Project Presentations

- **5-min lightning talks**

  Submit on grade scope by Noon (PDF)

- **Participation Bonus, if you ask questions :)**

  (5% of the class total for participation)

Motion-compensated Target Residual

Project Presentations

EE274_ProjectSignUp

Project Title	Student 1	Student 2	Student 3	Mentor	Feedback Provided	Presentation Group
RL for compression	Dilip			Tsachy, Shubham	Done	Group 3
LZ77 optimized implementation	Chendi	Jamie		Shubham	Done	Group 1
Lossless Image compression (PNG, QOI...)	Kelly	Katherine		Kedar	Done	Group 3
Compressor as Estimator for Neural Science	Pumiao Yan			Tsachy, Pulkit	Done	Group 2
Bits back coding etc.	Yifei Wang			Kedar	Done	Group 1
MRI data compression	Daniel			Kedar	Done	Group 2
Reproducing Learnt Image Compression in SCL	Cesar Lema			Pulkit	Done	Group 3
Adaptive Huffman Decoding	Sudeep Narala	Raymond Yang		Shubham	Done	Group 1
Tabular data compression using Chow-Liu trees	Jagriti Dixit			Pulkit, Dmitri	Done	Group 2
Perceptual Image Metrics	Shawn			Pulkit	Done	Group 3
Alias Coding	Anesu			Kedar, Pulkit	Done	Group 1
HW implementation of Huffman, tANS/rANS	Ian			Kedar	Done	Group 1
AAC (advanced audio codec)	Audrey	Oliver		Shubham	Done	Group 3
LZ78 optimized implementation	Luc			Shubham	Done	Group 1
Invesitgation of lossy compression as denoiser for audio	Jay			Tsachy, Pulkit	Done	Group 2
Lossy compression for Quantum computing	Noah	Dorsa		Tsachy, Pulkit/Shubham	Done	Group 2
Lossy text compression	Thomas	Lara		Tsachy, Shubham	Done	Group 3
CTW	Matthew			Shubham	Done	Group 1

Video Compression

EE274

Kedar Tatwawadi

Video Is Growing and Innovating

82%
of the internet will be video by 2021

300%
annual increase of YouTube home page hits

23%
video analytics CAGR over next 6 years

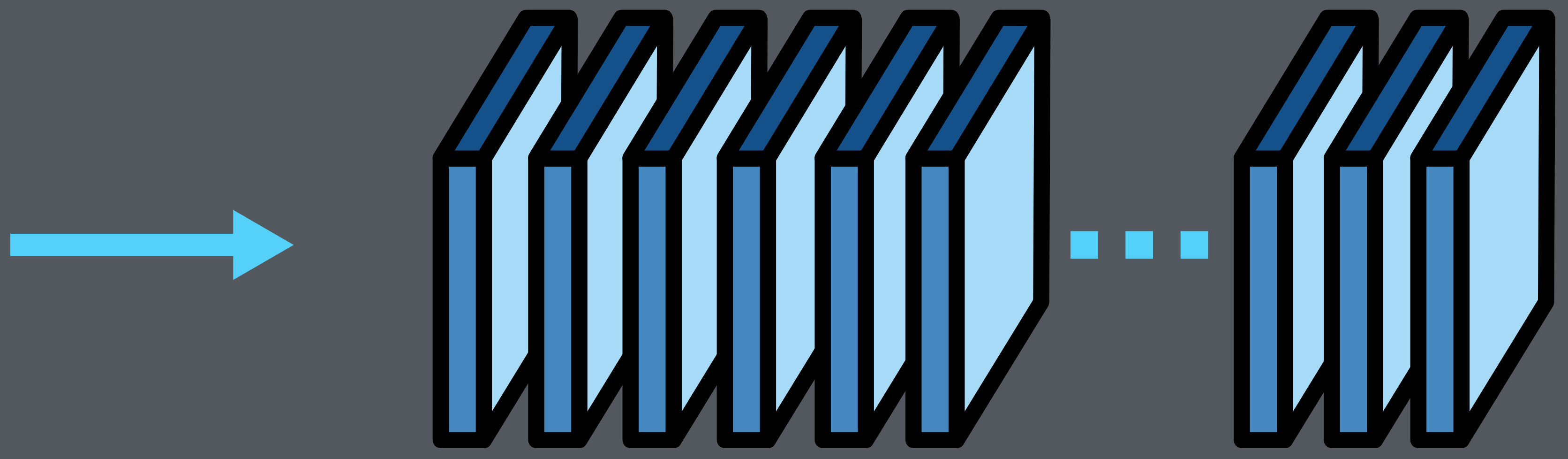
14B /day
videos on Snap

45 billion
cameras in the world by 2022

References: Cisco Visual Networking Index, YouTube, Snap

Video Compression

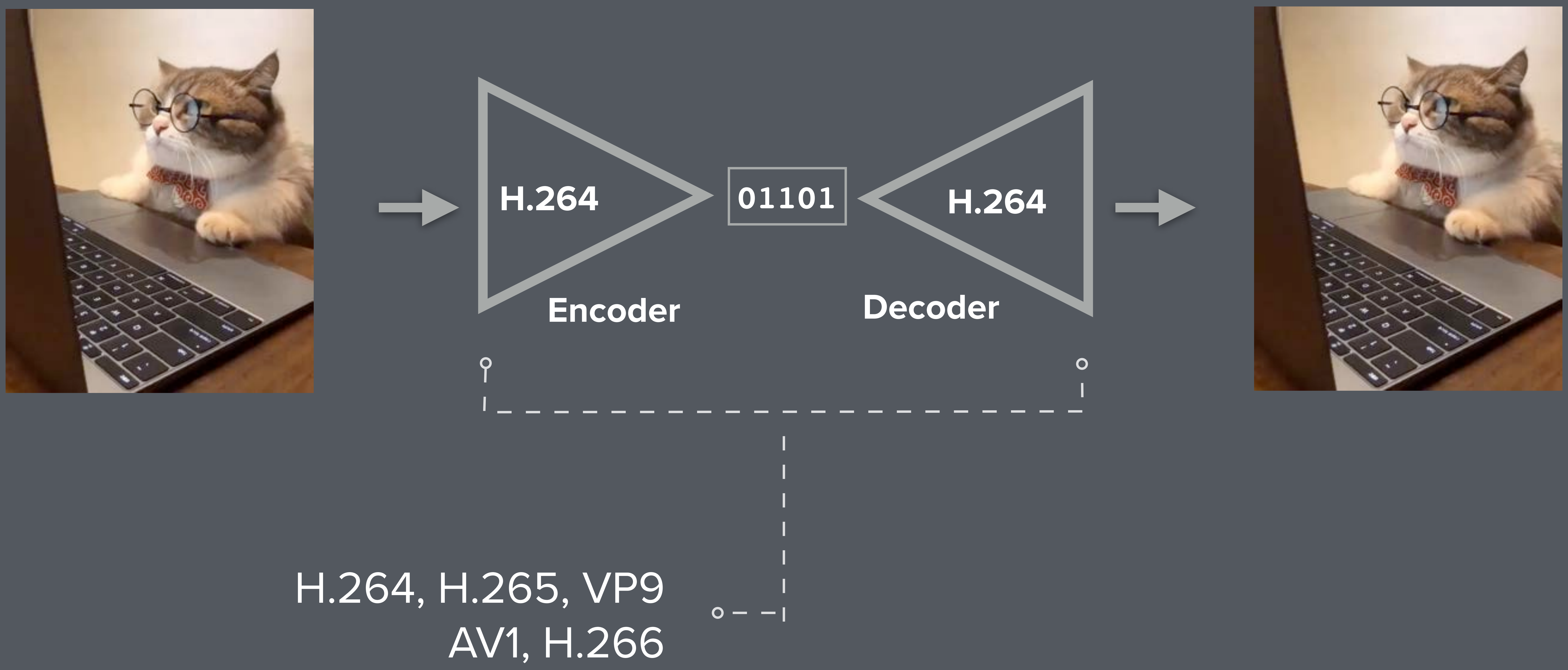
Target Video



Frames

- Video = *"Motion Pictures"*

Traditional Video Codecs

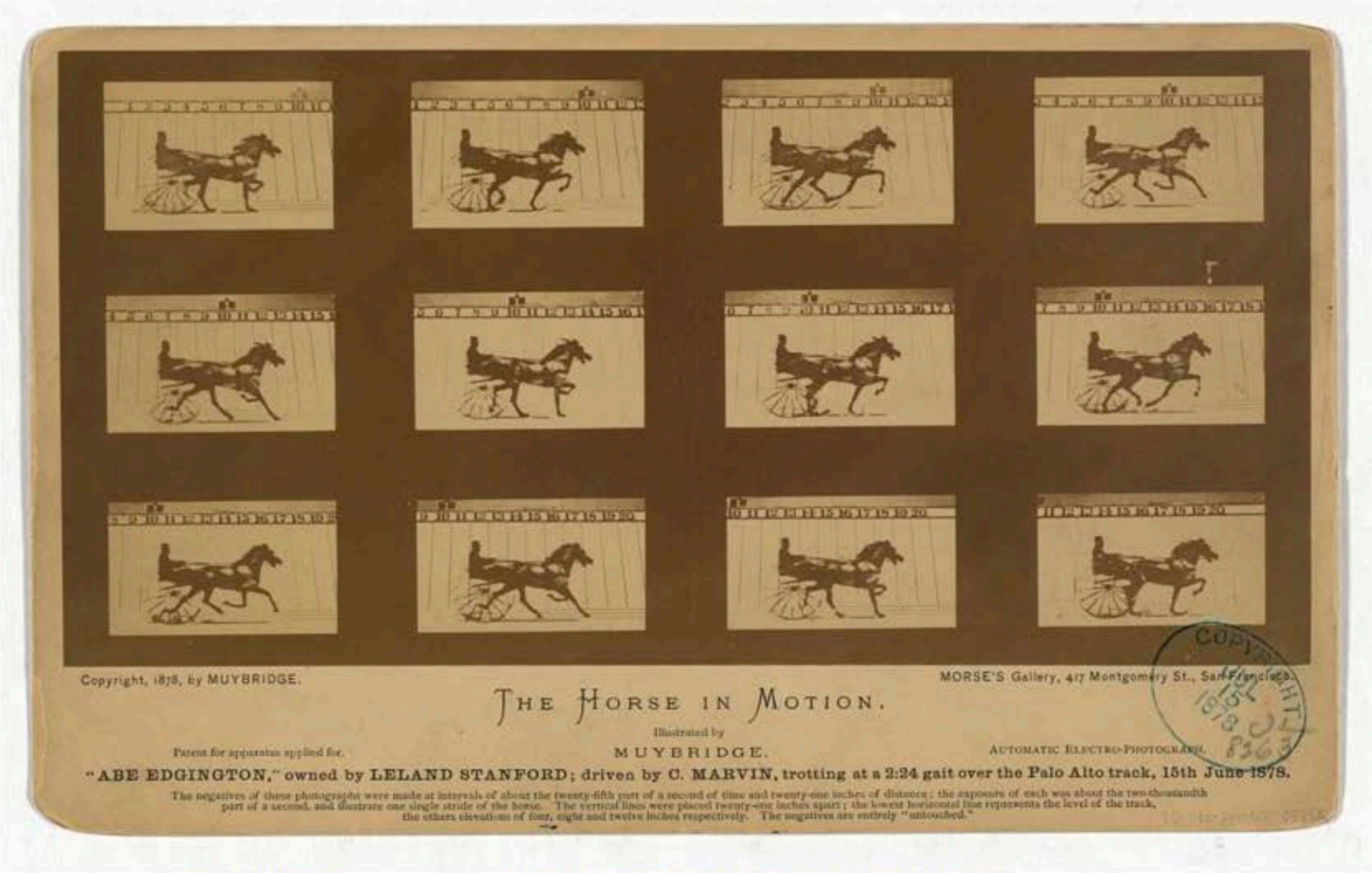


First “video” ever captured

File:The Horse in motion. "Abe Edgington," owned by Leland Stanford; driven by C. Marvin, trotting at a 2-24 gait over the Palo Alto track, 15th June 1878 LOC 13624627695.jpg

From Wikipedia, the free encyclopedia

File | File history | File usage | Global file usage



Size of this preview: 800 × 509 pixels. Other resolutions: 320 × 204 pixels | 640 × 408 pixels | 1,024 × 652 pixels.

Jockey 720p

- FPS= frames/sec -> 30
- X,Y -> 720x1280

Jockey 720p


```
[→  jockey_videos mediainfo jockey_720p.y4m
General
Complete name                            : jockey_720p.y4m
Format                                   : YUV4MPEG2
File size                                : 169 MiB
Duration                                 : 4 s 267 ms
Overall bit rate                         : 332 Mb/s

Video
Format                                   : YUV
Duration                                 : 4 s 267 ms
Bit rate                                 : 332 Mb/s
Width                                    : 1 280 pixels
Height                                   : 720 pixels
Display aspect ratio                     : 16:9
Frame rate                               : 30.000 FPS
Color space                              : YUV
Chroma subsampling                       : 4:2:0
Scan type                                : Progressive
Compression mode                         : Lossless
Bits/(Pixel*Frame)                       : 12.000
Stream size                              : 169 MiB
```

Jockey 720p -> H264 CRF20


```
~ ffmpeg -y -i jockey_720p.y4m -codec:v libx264 -crf 20 -x264-params keyint=8:bframes=0 jockey_crf20.mp4
```

- RAW -> 332 Mb/s
- CRF20 -> 6.2 Mb/s

(PSNR -> 43)

Jockey 720p -> H264 CRF40

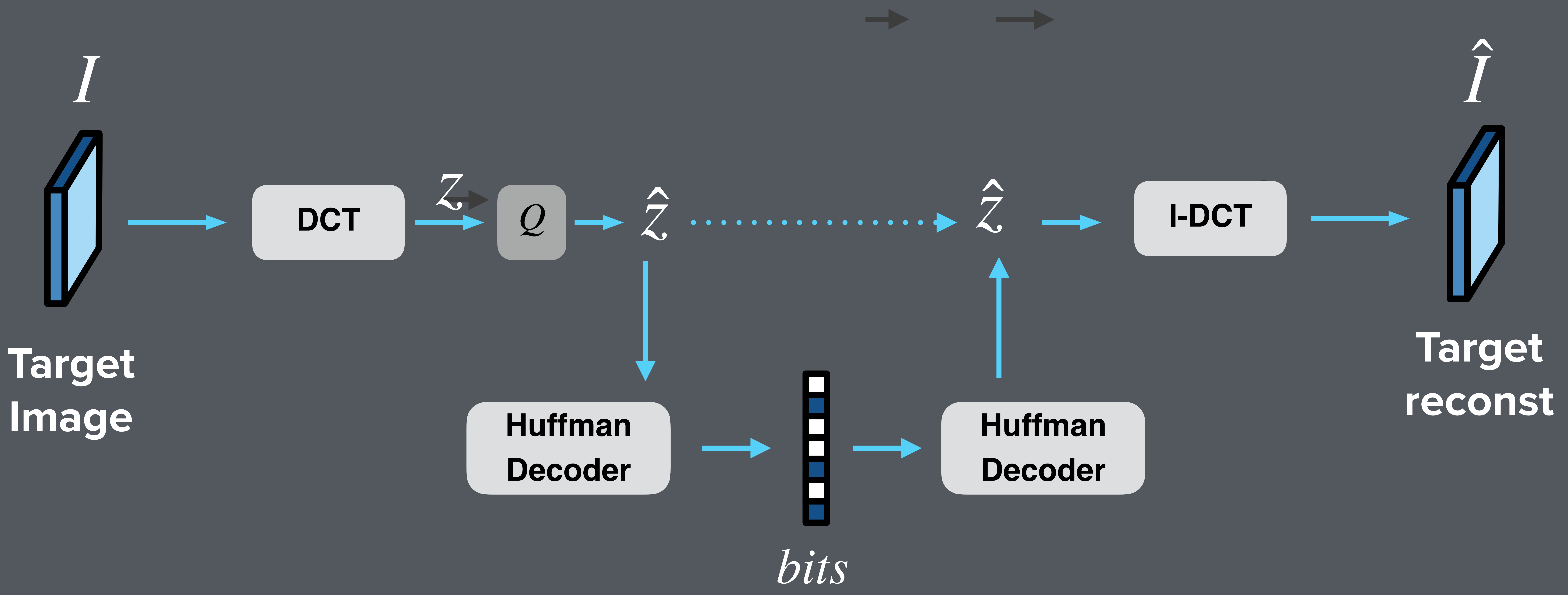

```
~ ffmpeg -y -i jockey_720p.y4m -codec:v libx264 -crf 20 -x264-params keyint=8:bframes=0 jockey_crf20.mp4
```

- RAW -> 332 Mb/s
- CRF20 -> 6.2 Mb/s

  (PSNR -> 43)
- CRF40 -> 0.8 Mb/s

  (PSNR -> 33)

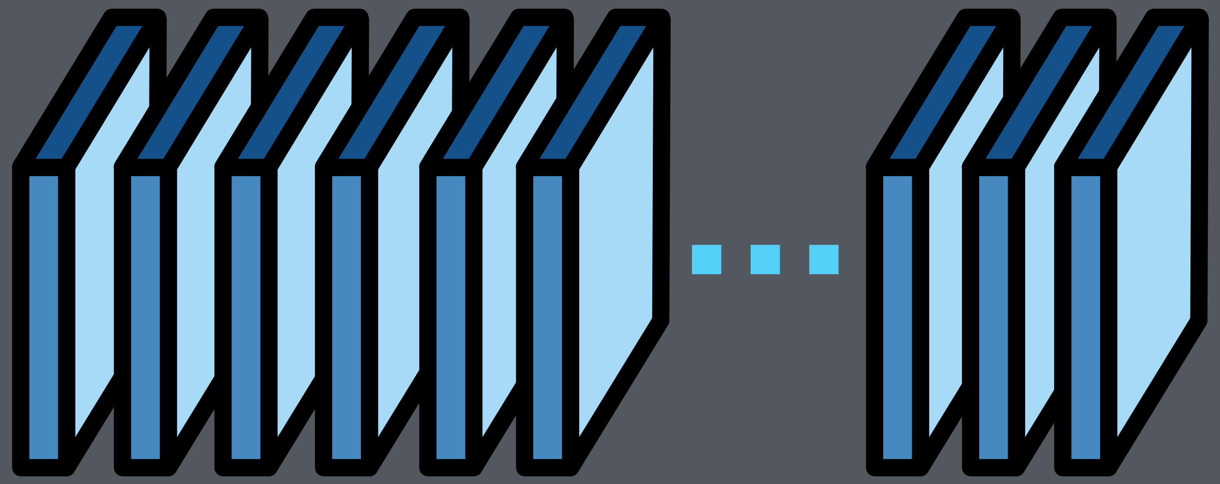
JPEG -> Recap



Goal: $\min_{L(bits) \leq B} d(I, \hat{I})$

Compressing Video as I-frames

Target Video



Compress each frame like a Image (I-frame)

Jockey 720p -> Iframe compression

- RAW -> 332 Mb/s
- CRF20, I-frame -> 9 Mb/s

(PSNR -> 44)

Frame 0

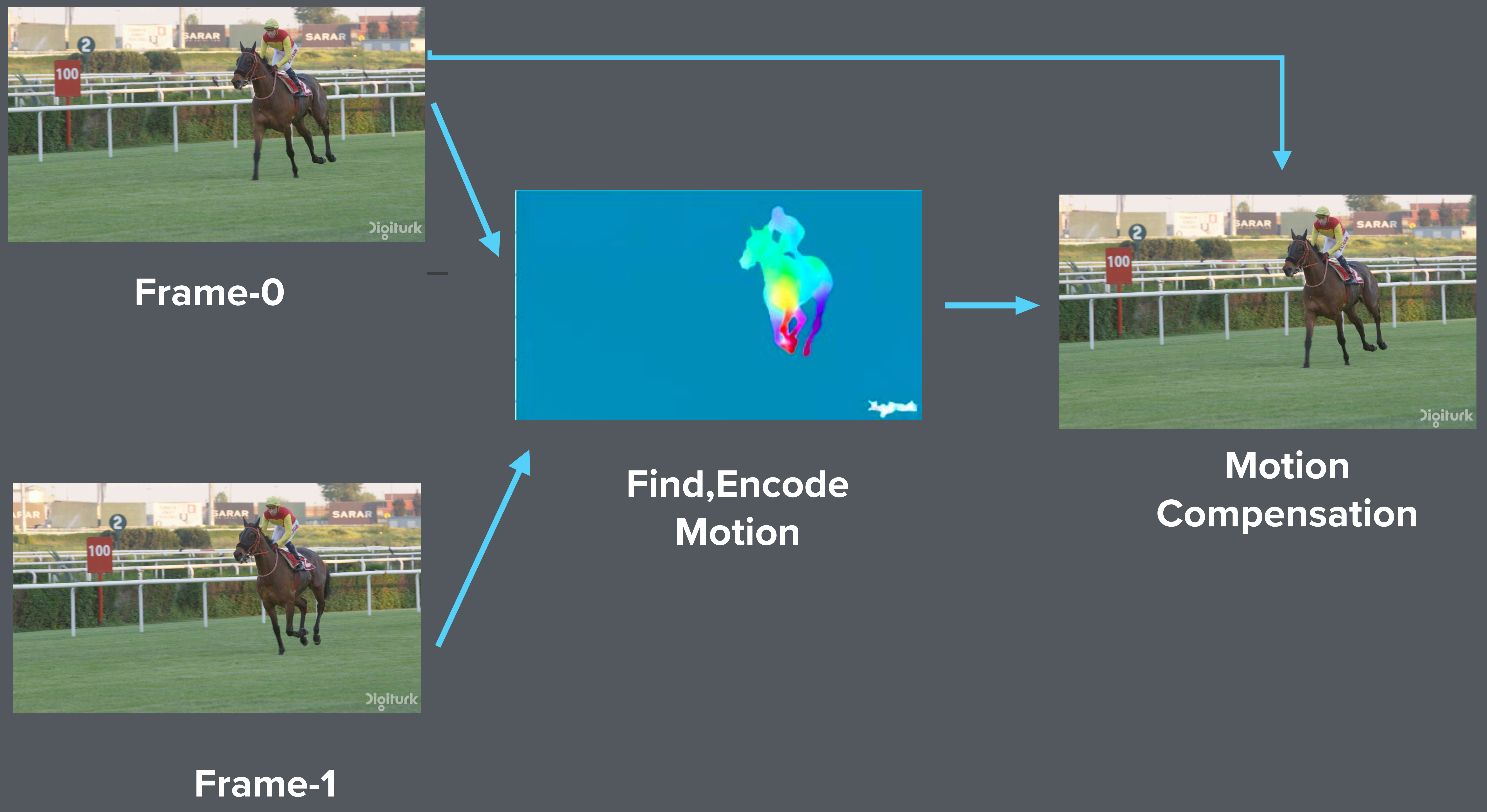
Frame 1

Compressing the second frame

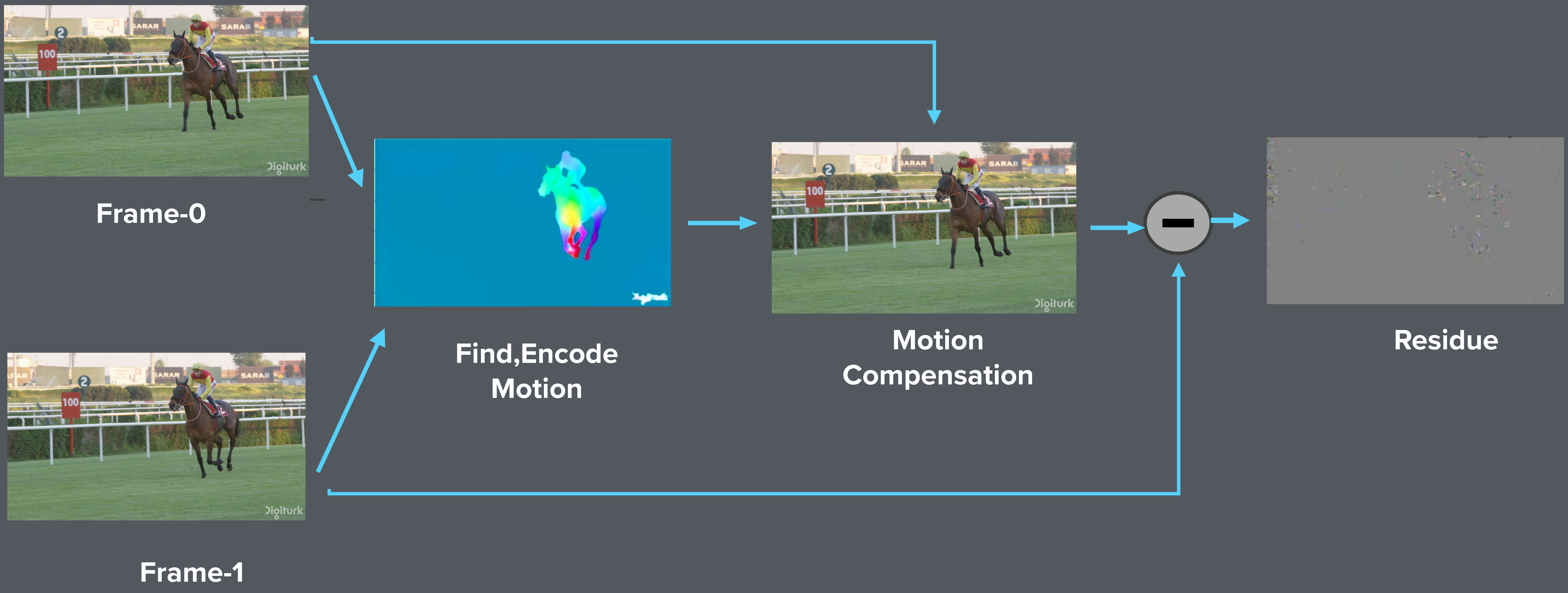
Frame-0

Frame-1

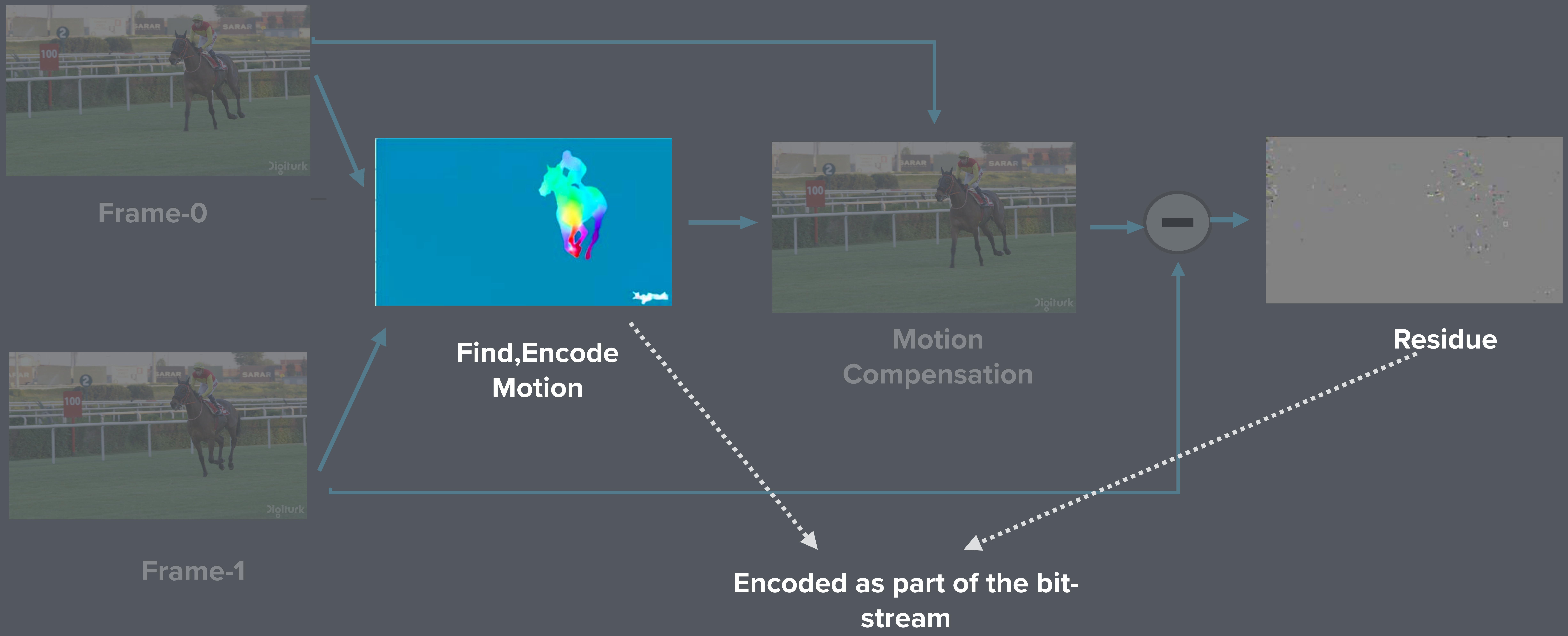
Compressing the second frame



Compressing the second frame

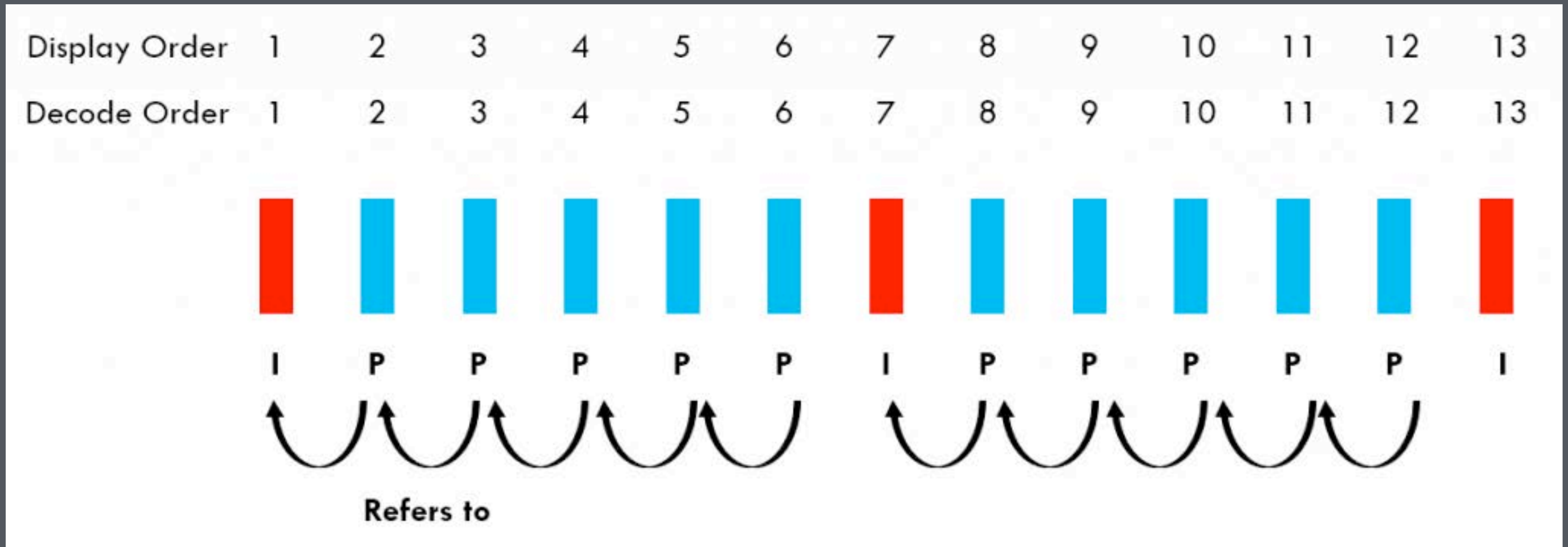


Compressing the second frame



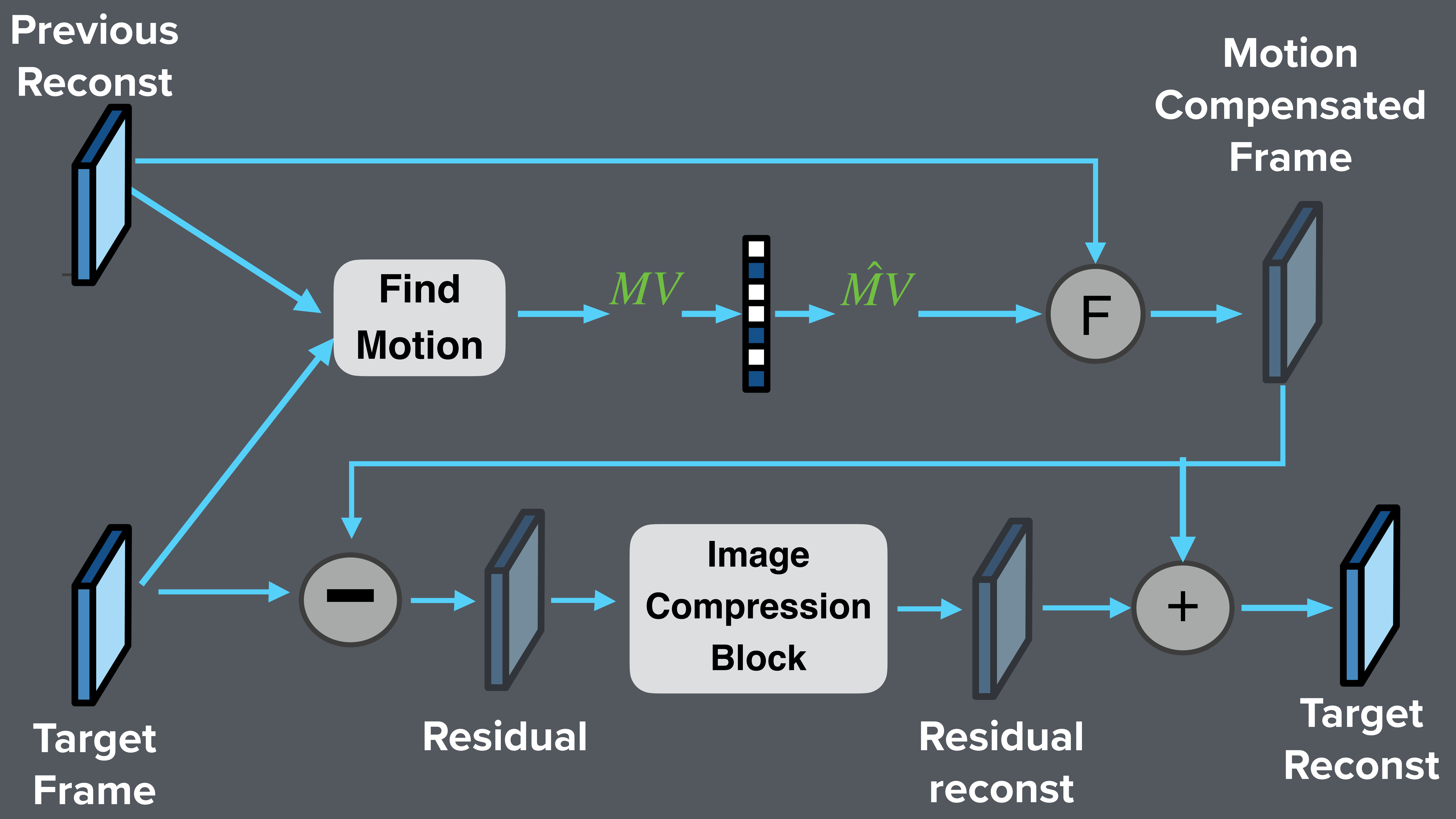
I-P frame coding

Target Video



- P-frame -> “prediction frame”
- Predict based on the previous frame
- **Keyint -> 6** (every 6th frame an I-frame)

IP-coding



Motion-compensated

Target

Residual

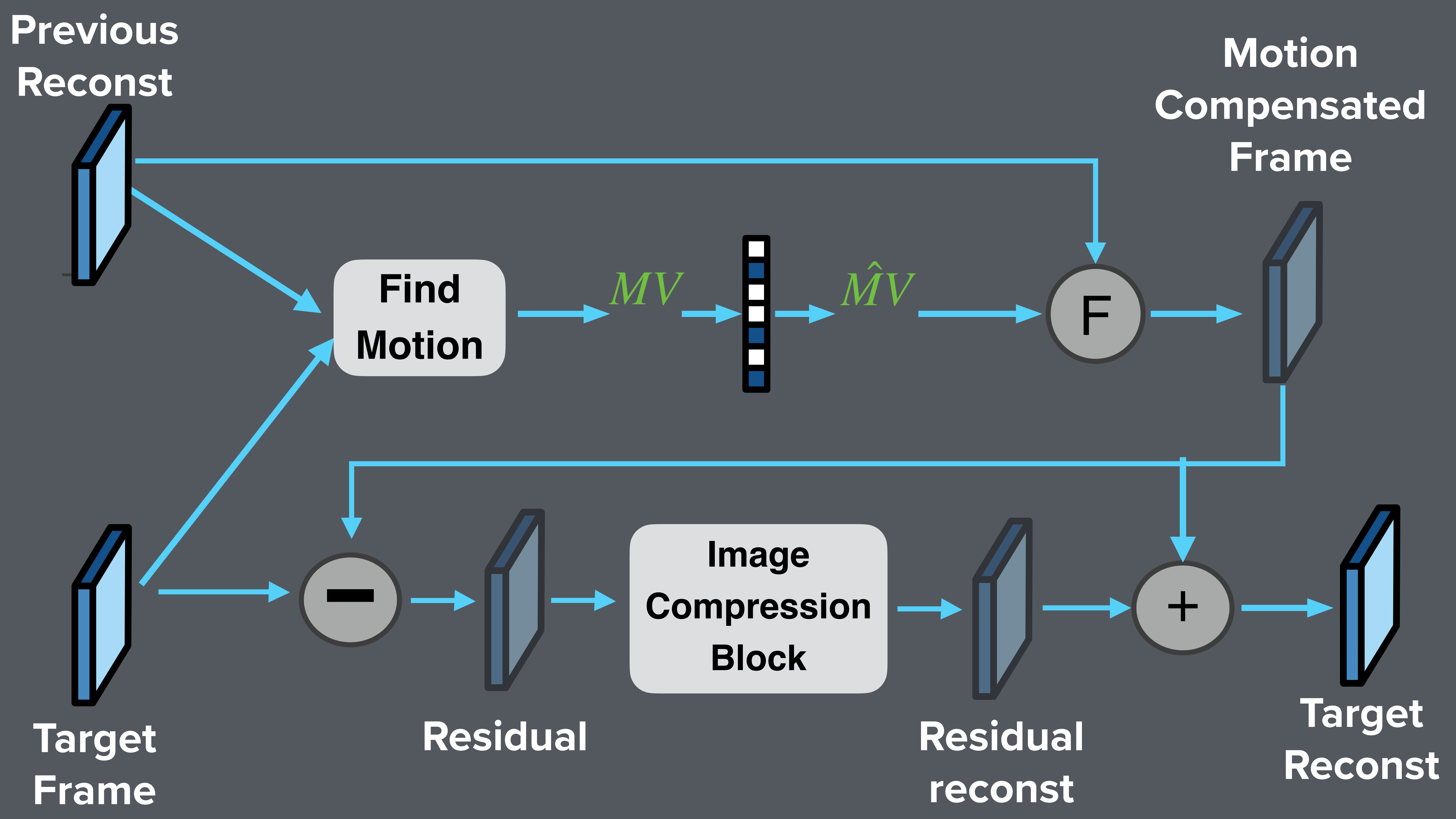
Jockey 720p -> H264 CRF20

- RAW -> 332 Mb/s
- CRF20 -> 6.2 Mb/s

(PSNR -> 43)

```
~ ffmpeg -y -i jockey_720p.y4m -codec:v libx264 -crf 20 -x264-params keyint=8:bframes=0 jockey_crf20.mp4
```

IP-coding

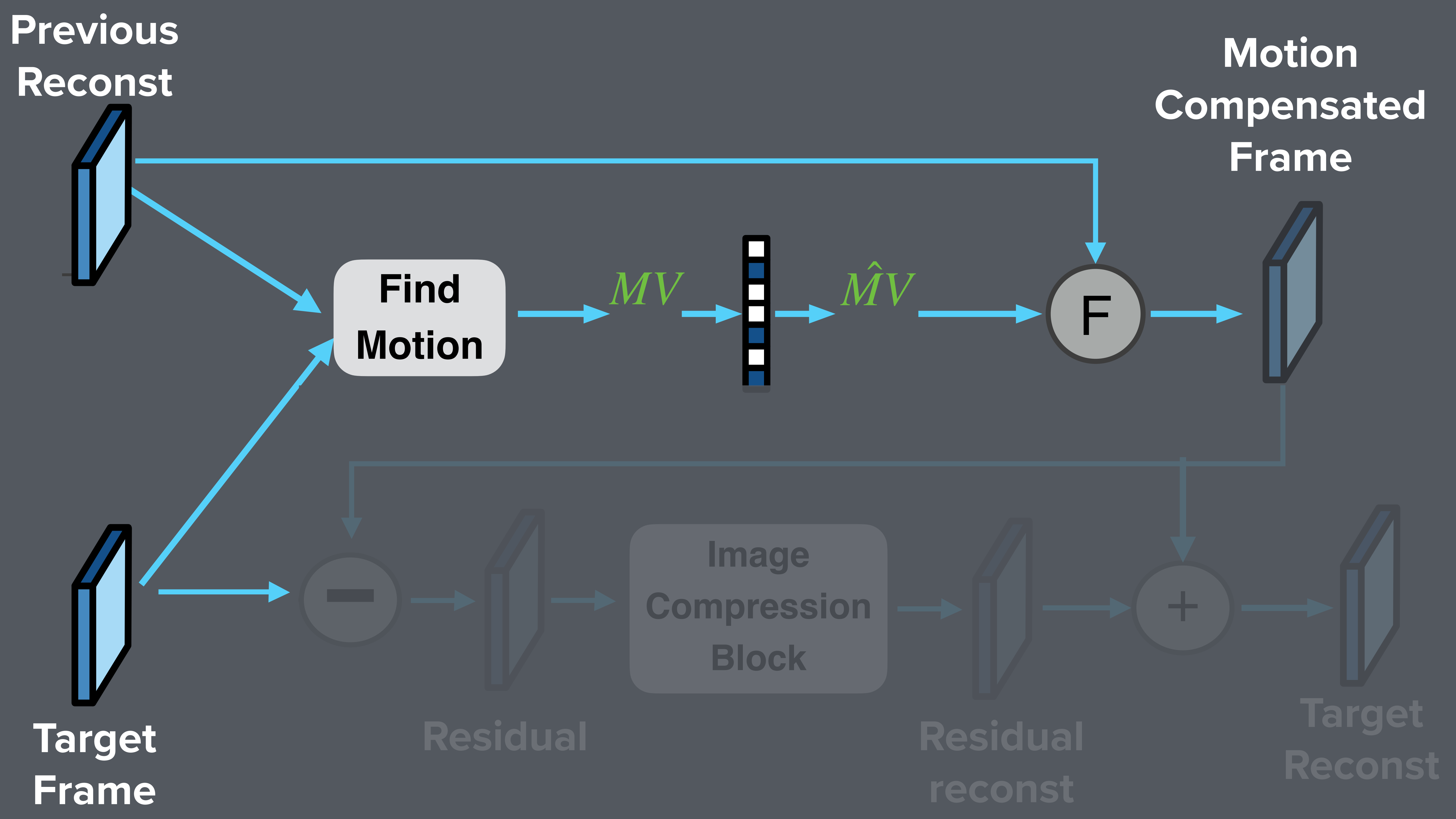


Motion-compensated

Target

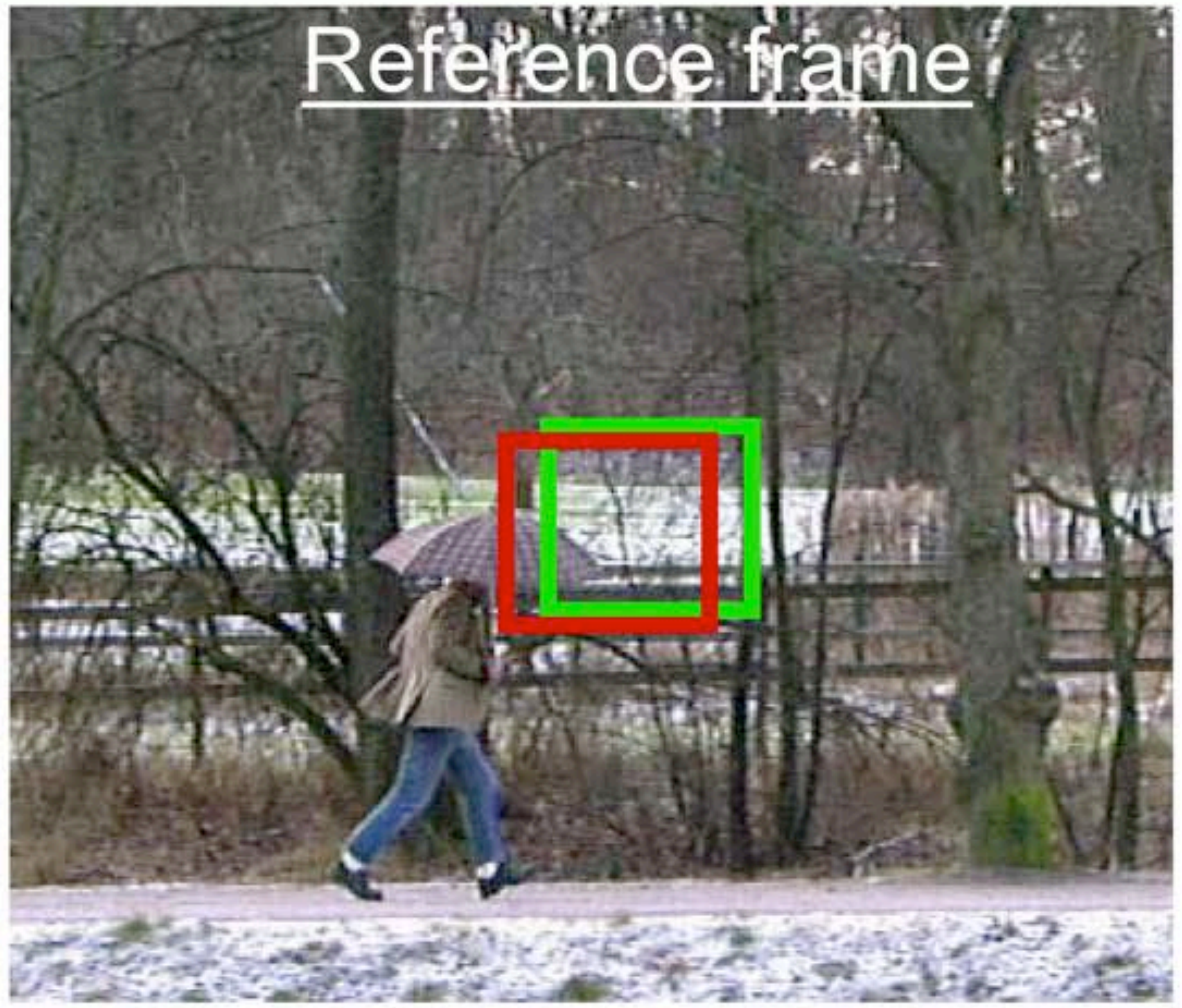
Residual

IP-coding



Motion-compensated Target Residual

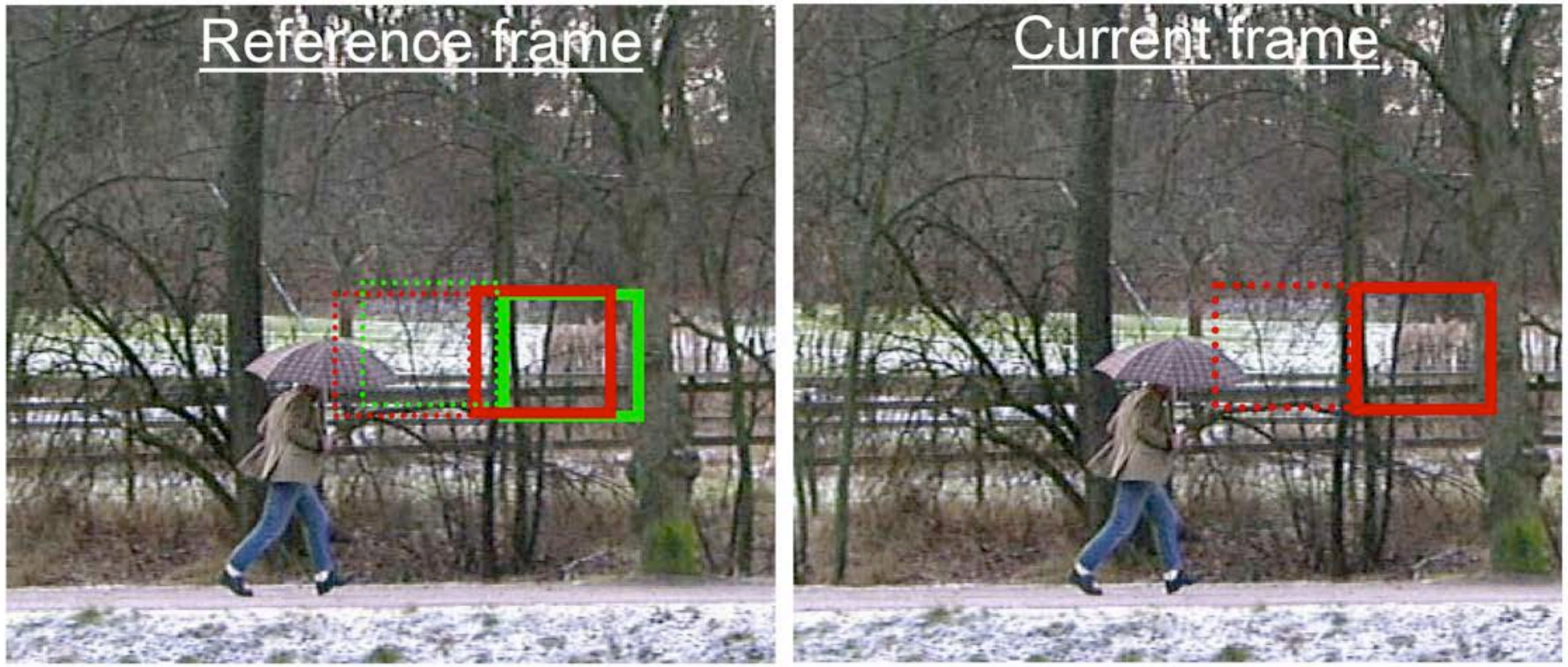
Block-matching algorithm



Block is compared with a shifted array of pixels in the reference frame to determine the best match

Block of pixels is considered

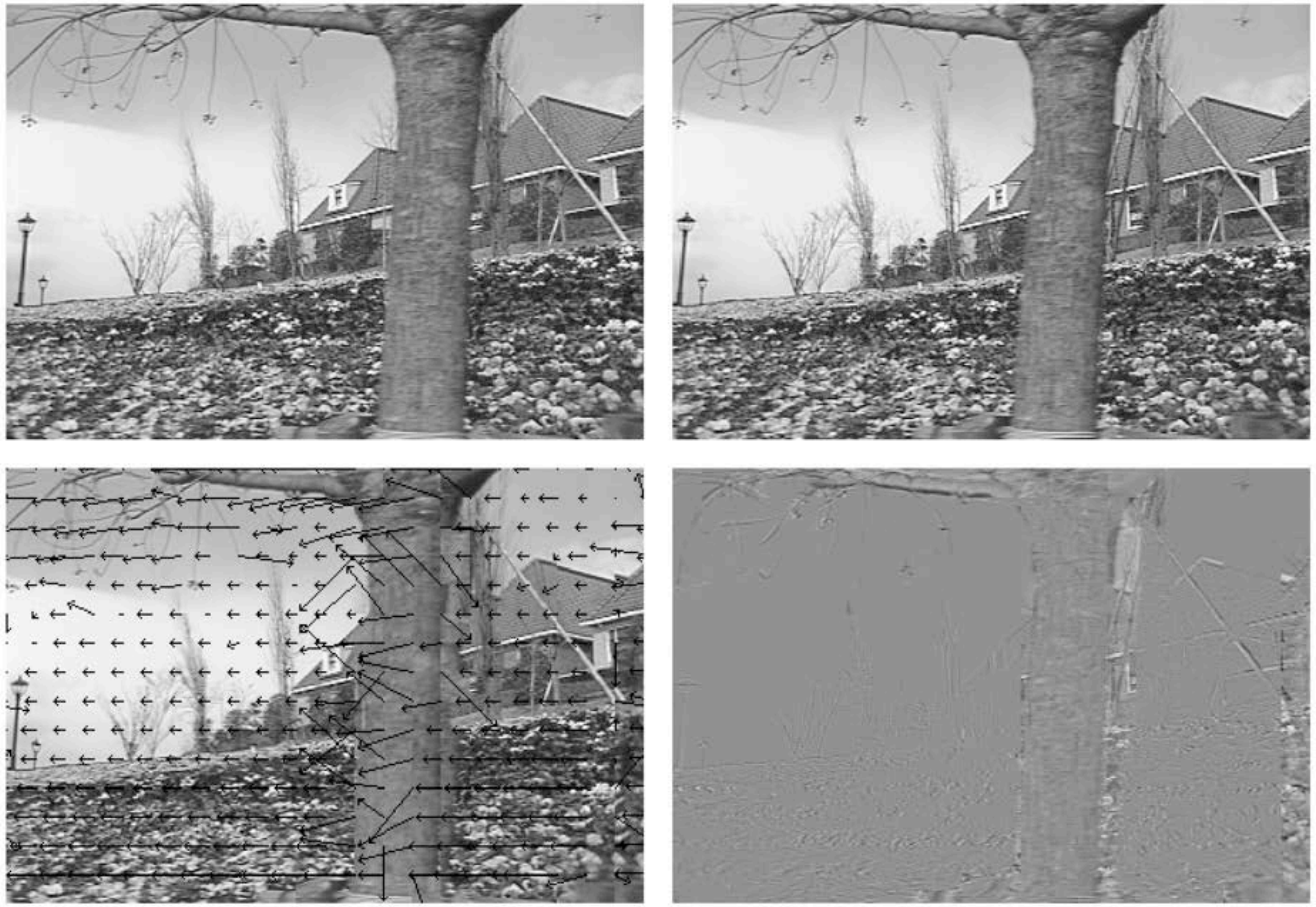
Block-matching algorithm



. . . process repeated for the next block

Motion-compensated prediction: example

Previous frame　　　Current frame

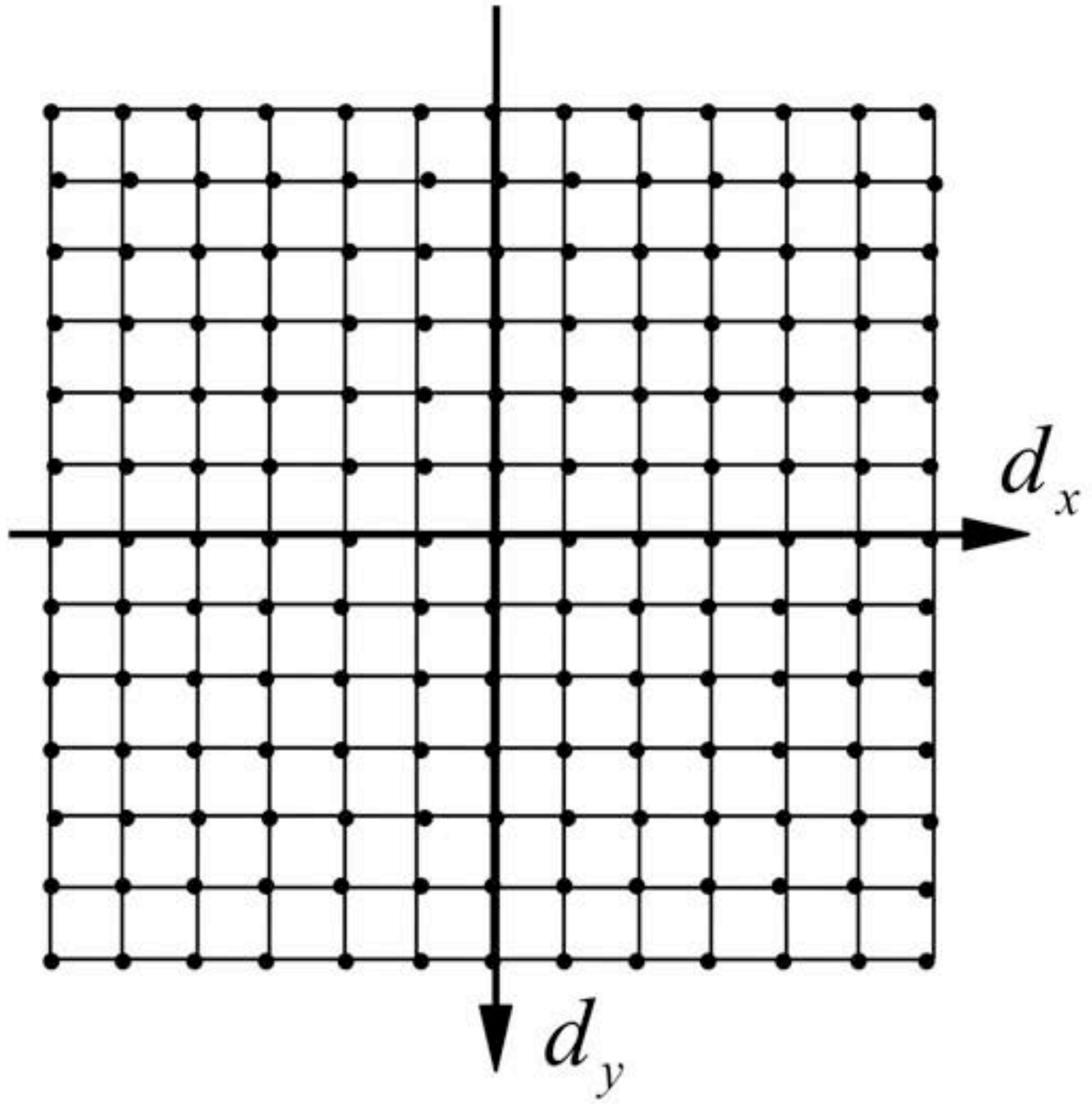


Current frame with displacement vectors　　　Motion-compensated Prediction error

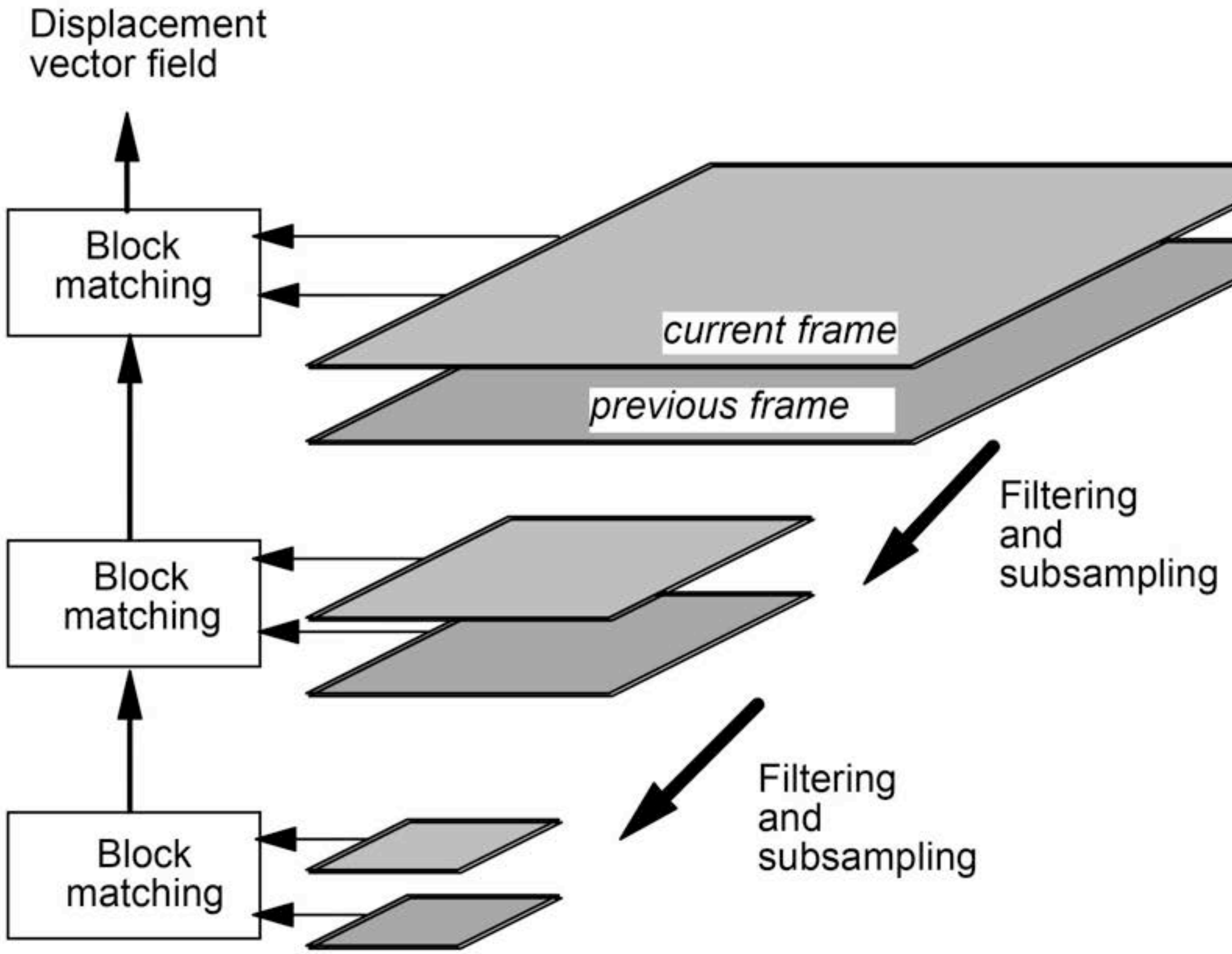
Blockmatching: search strategies I

Full search

- All possible displacements within the search range are compared.
- Computationally expensive
- Highly regular, parallelizable

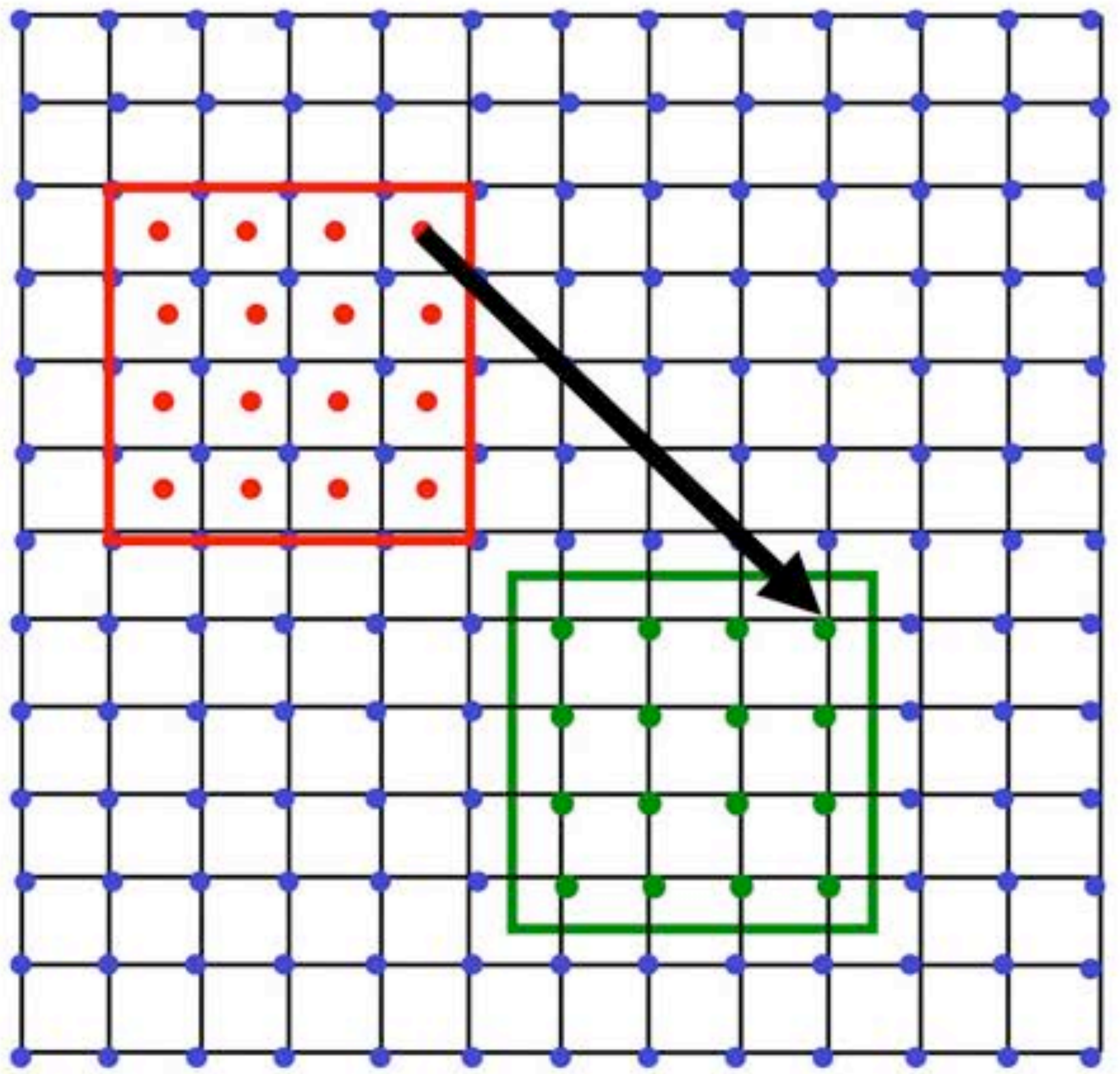


Hierarchical blockmatching



Sub-pel accuracy

- Interpolate pixel raster of the reference frame to desired fractional pel accuracy (e.g., by bi-linear interpolation)
- Straightforward extension of displacement vector search to fractional accuracy
- Example: half-pel accurate displacements



$$\begin{pmatrix} d_x \\ d_y \end{pmatrix} = \begin{pmatrix} 4.5 \\ 4.5 \end{pmatrix}$$

Case Study -> Foreman Video

- Size: 352x288
- CRF20, H264
- Keyint = 8

  (I frame at 0,8,16,...

  P-frame otherwise)

Case Study -> Jockey CRF20


```
~ ffmpeg -y -i jockey_720p.y4m -codec:v libx264 -crf 20 -x264-params keyint=8:bfreames=0 jockey_crf20.mp4
```

- RAW -> 332 Mb/s
- CRF20 -> 6.2 Mb/s

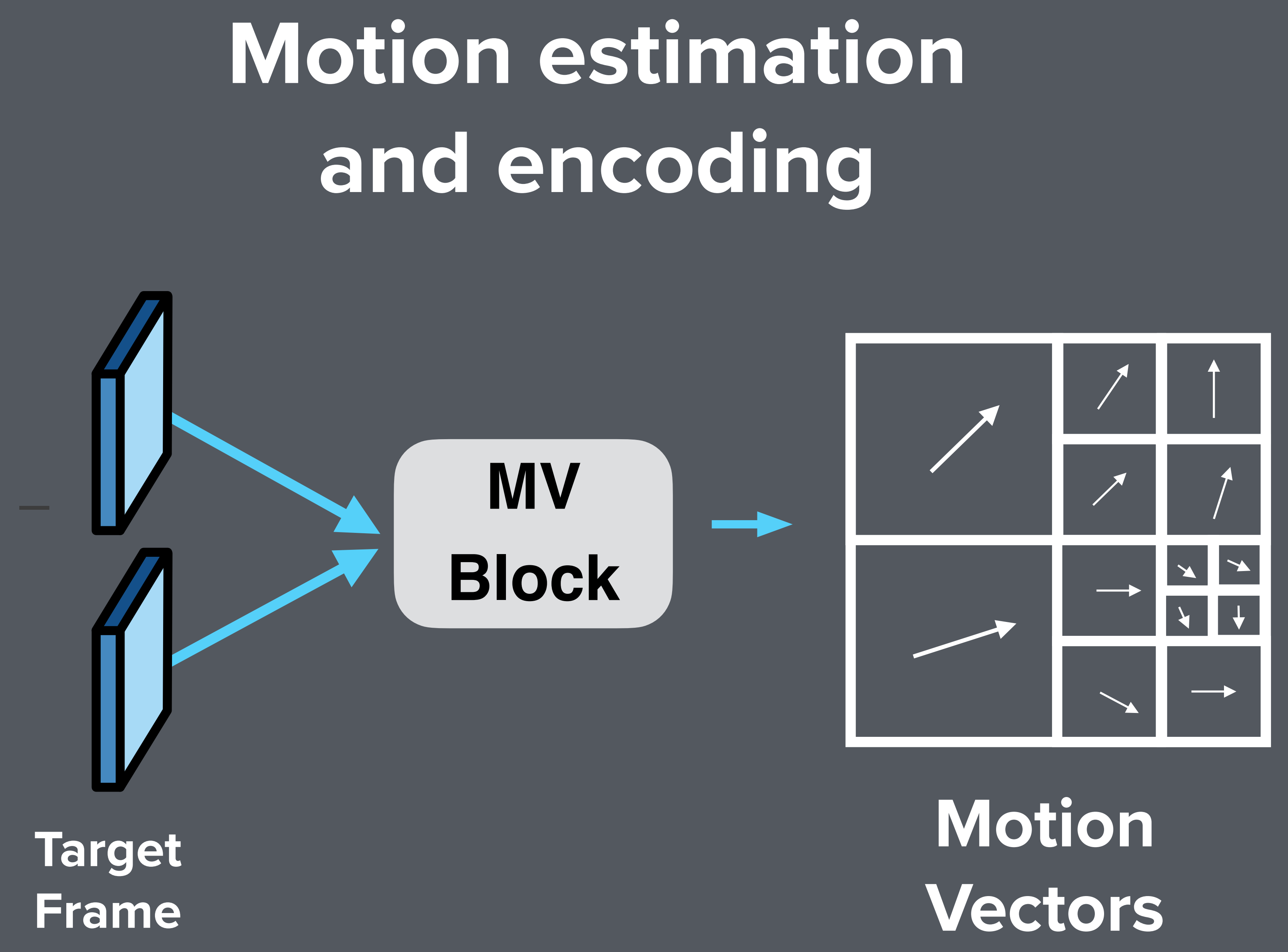
(PSNR -> 43)

Case Study -> Jockey CRF20


```
(base) (wovenv) → jockey_videos mediainfo jockey_crf20.mp4
General
Complete name                            : jockey_crf20.mp4
Format                                   : MPEG-4
Format profile                           : Base Media
Codec ID                                 : isom (isom/iso2/avc1/mp41)
File size                                : 3.16 MiB
Duration                                 : 4 s 267 ms
Overall bit rate                         : 6 219 kb/s
Writing application                      : Lavf58.29.100

Video
ID                                       : 1
Format                                   : AVC
Format/Info                              : Advanced Video Codec
Format profile                           : High@L3.1
Format settings                          : CABAC / 3 Ref Frames
Format settings, CABAC                   : Yes
Format settings, Reference frames        : 3 frames
Format settings, GOP                     : M=1, N=8
Codec ID                                 : avc1
Codec ID/Info                            : Advanced Video Coding
Duration                                 : 4 s 267 ms
Bit rate                                 : 6 217 kb/s
Width                                    : 1 280 pixels
Height                                   : 720 pixels
Display aspect ratio                     : 16:9
Frame rate mode                          : Constant
Frame rate                               : 30.000 FPS
Color space                              : YUV
Chroma subsampling                       : 4:2:0
Bit depth                                : 8 bits
Scan type                                : Progressive
Bits/(Pixel*Frame)                       : 0.225
Stream size                              : 3.16 MiB (100%)
Writing library                          : x264 core 155 r2917 0a84d98
Encoding settings                        : cabac=1 / ref=3 / deblock=1:0:0 / ana
lyse=0x3:0x113 / me=hex / subme=7 / psy=1 / psy_rd=1.00:0.00 / mixed_ref=1 / me_
range=16 / chroma_me=1 / trellis=1 / 8x8dct=1 / cqm=0 / deadzone=21,11 / fast_ps
kip=1 / chroma_qp_offset=-2 / threads=22 / lookahead_threads=3 / sliced_threads=
0 / nr=0 / decimate=1 / interlaced=0 / bluray_compat=0 / constrained_intra=0 / b
frames=0 / weightp=2 / keyint=8 / keyint_min=1 / scenecut=40 / intra_refresh=0 /
 rc_lookahead=8 / rc=crf / mbtree=1 / crf=20.0 / qcomp=0.60 / qpmin=0 / qpmax=69
 / qpstep=4 / ip_ratio=1.40 / aq=1:1.00
Codec configuration box                  : avcC
```

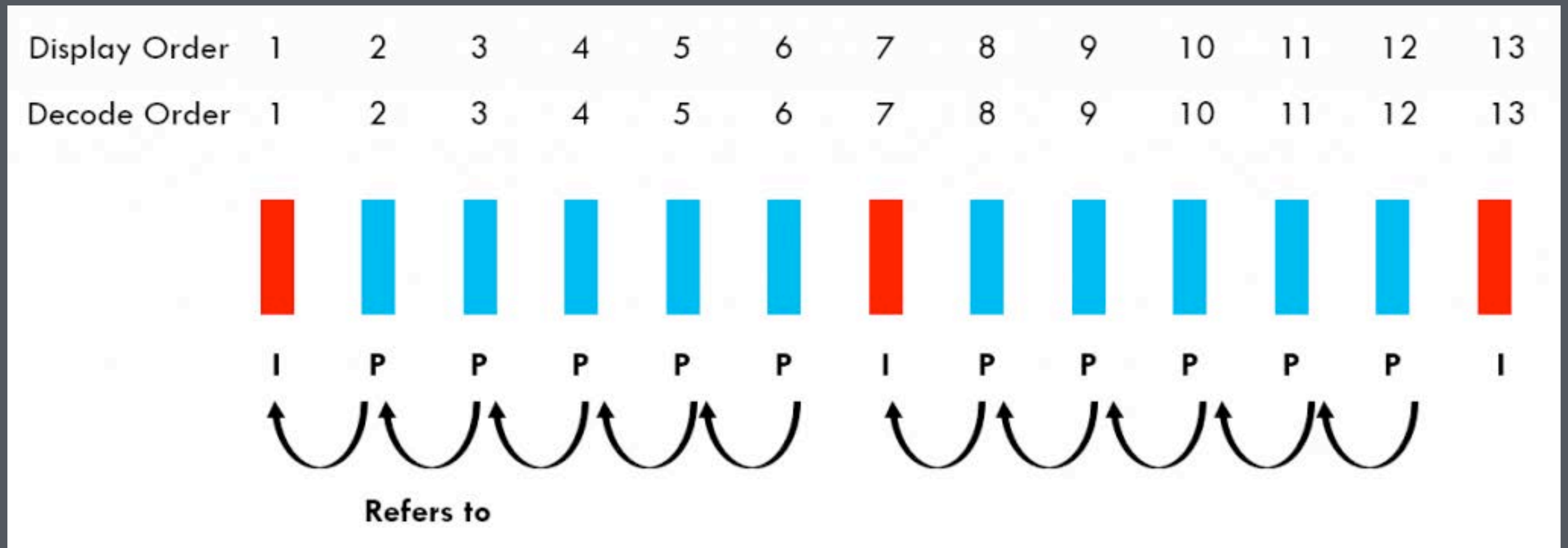
Iterative Block-search based Motion



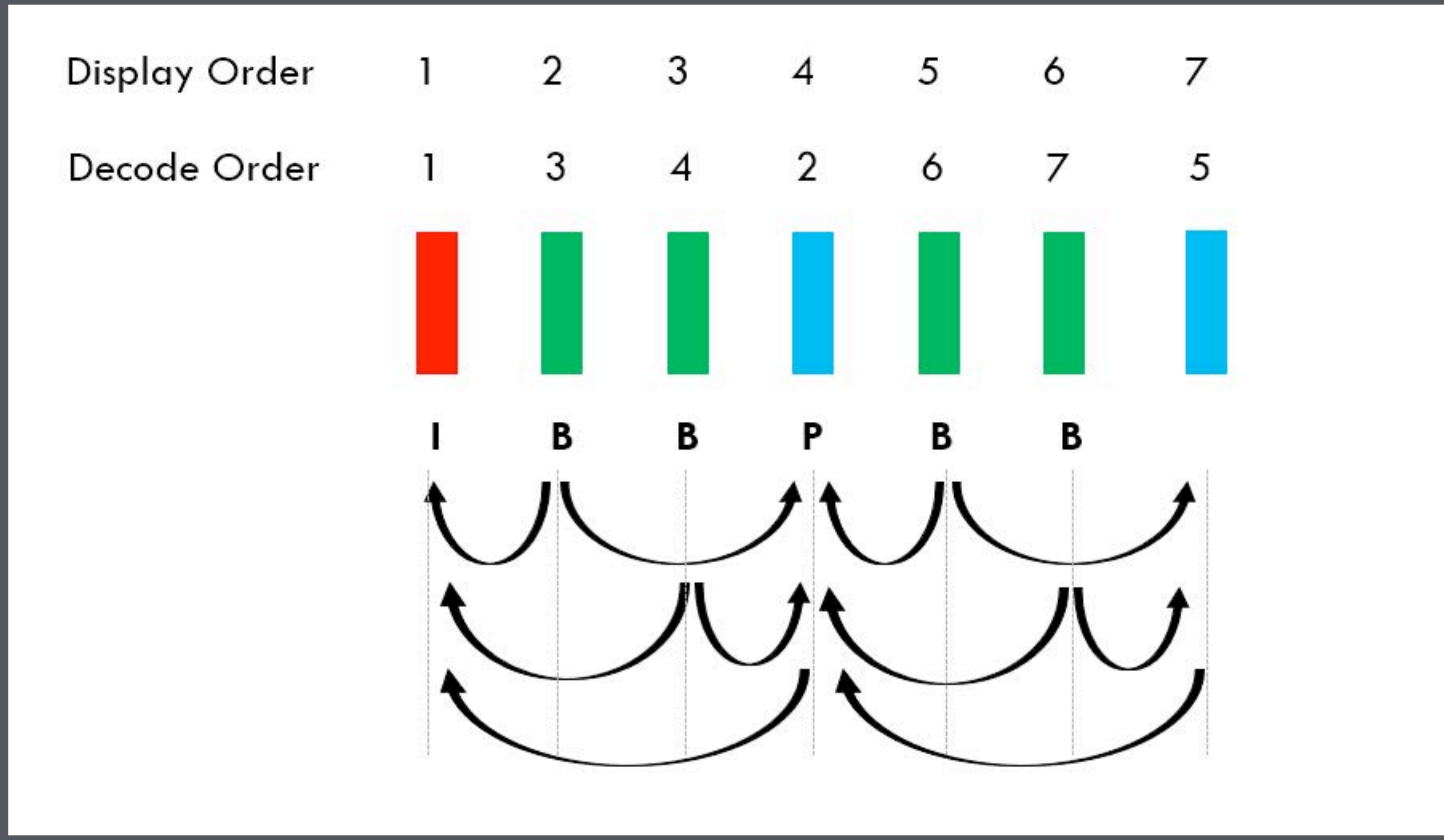
- Axis-aligned blocks, discretized motion directions and magnitudes
- Extremely efficient (with some algorithmic optimizations)
- Leads to significant blocky artifacts, needing some “de-blocking filtering” at the end

Motion-compensated Target Residual

I,P,B frame coding



IP-frame coding



IPB-frame coding

- **P-frame** -> “prediction frame” (only references past frame)
- **B-frame** -> references past and future frames.
- Interpolation vs Extrapolation

I,P,B frame types

- **I-Frames Only:**

  Simple, used in video editing softwares

- **I-Frames + P-Frames:**

  Better compression than I-frame only.

  Also called “low-latency/low-delay” mode. Used for video conferencing

- **I-Frames + P-Frames + B-Frames:**

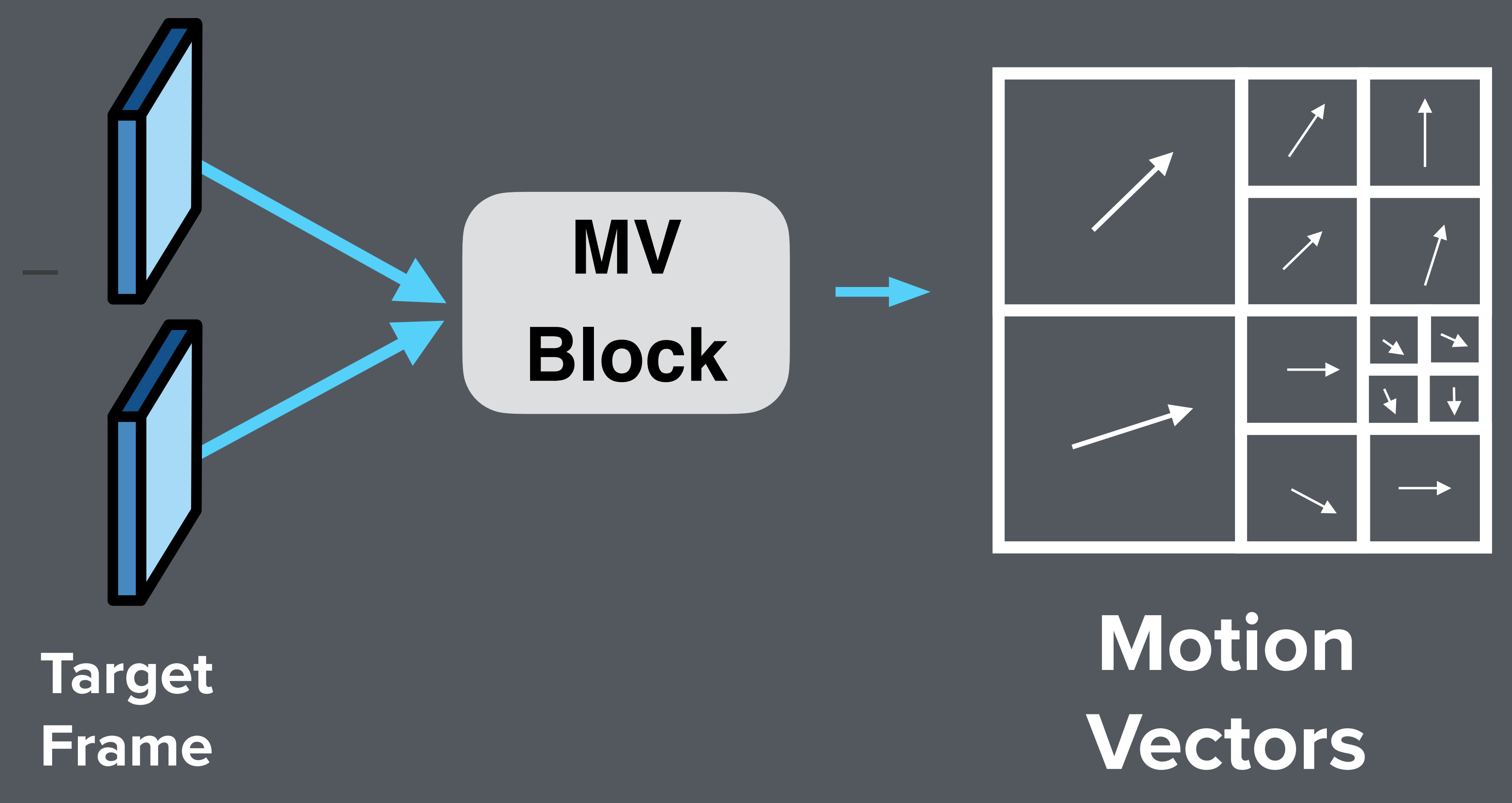
  Typically gives the best compression (also called “Random Access Mode”)

  Ideal for Video Streaming (Youtube, Netflix…)

Motion-compensated **Target** **Residual**

Iterative Block-search based Motion

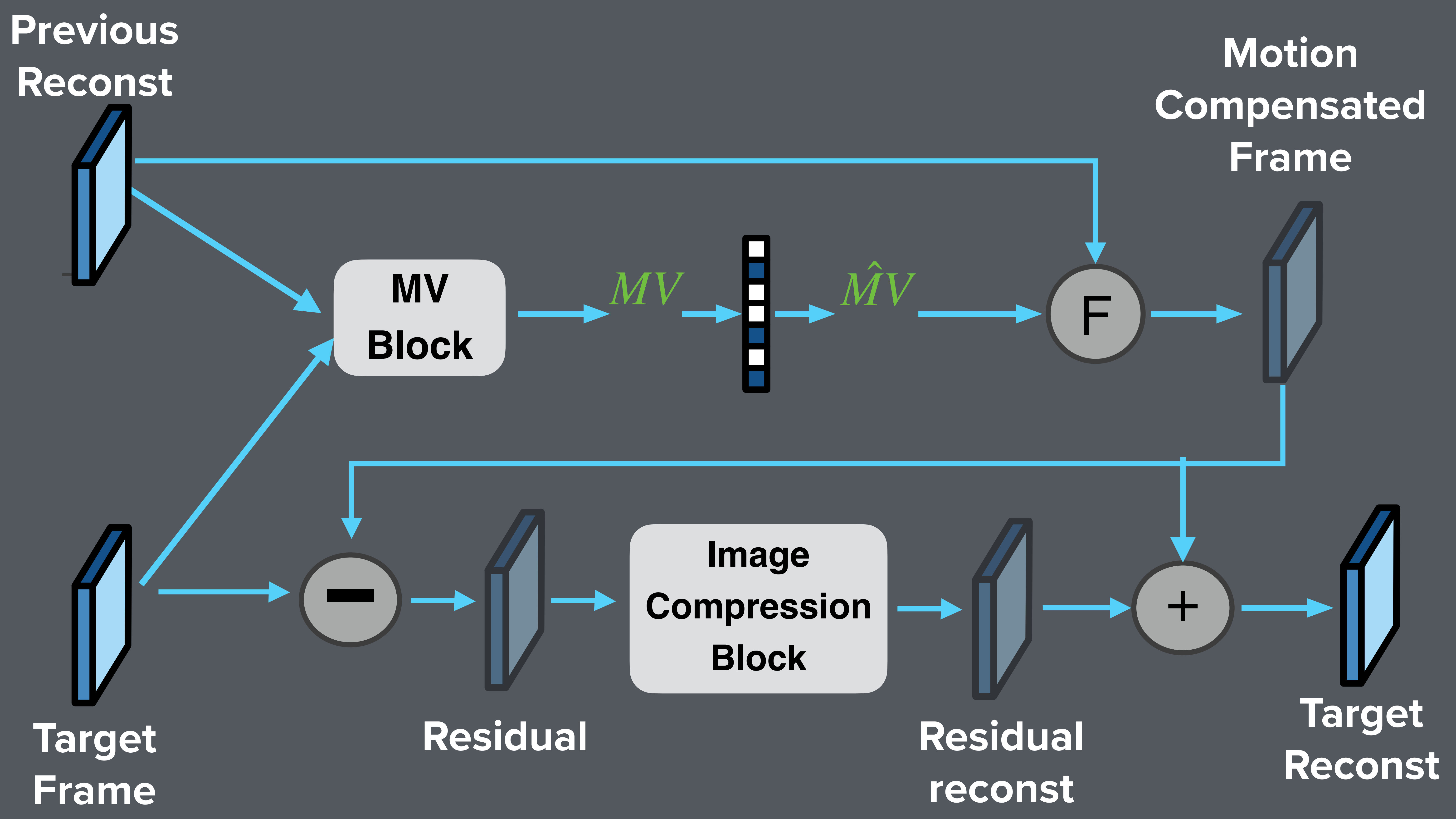
Motion estimation and encoding



- Axis-aligned blocks, discretized motion directions and magnitudes
- Extremely efficient (with some algorithmic optimizations)
- Leads to significant blocky artifacts, needing some “de-blocking filtering” at the end

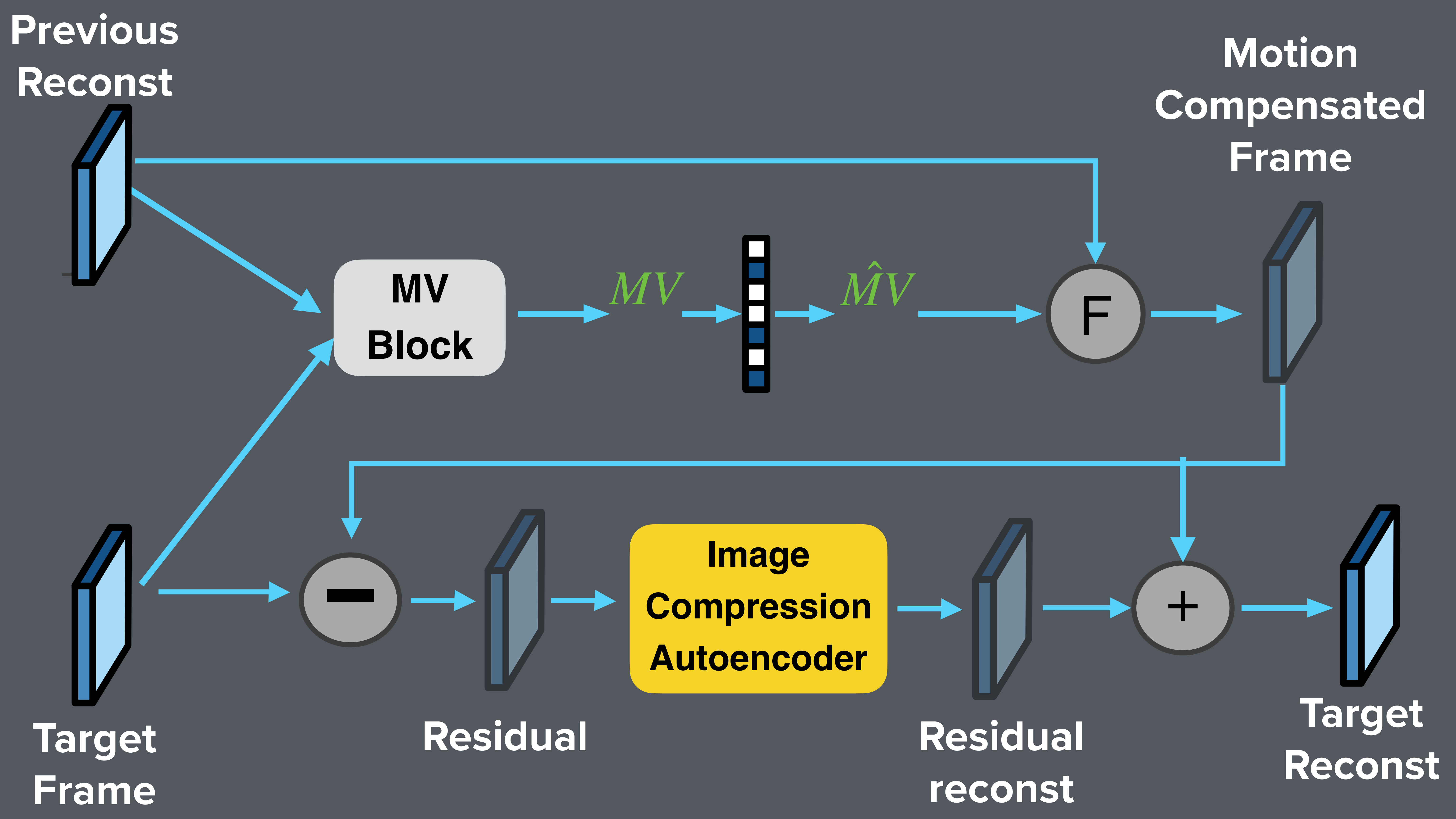
Motion-compensated Target Residual

Traditional IP coding



Motion-compensated Target Residual

IP coding -> ML-based

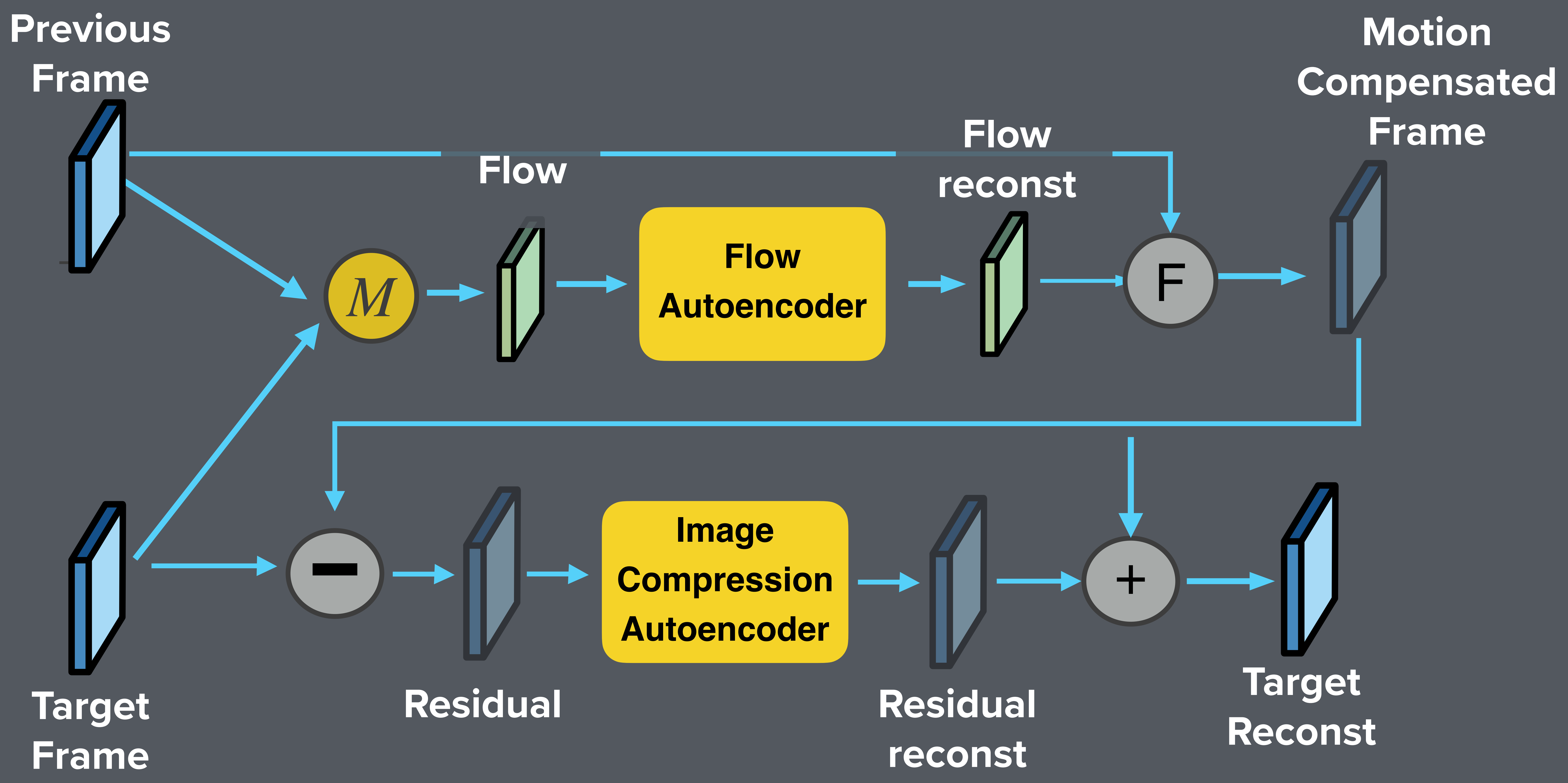


Motion-compensated

Target

Residual

End-to-End Learned Video Codec



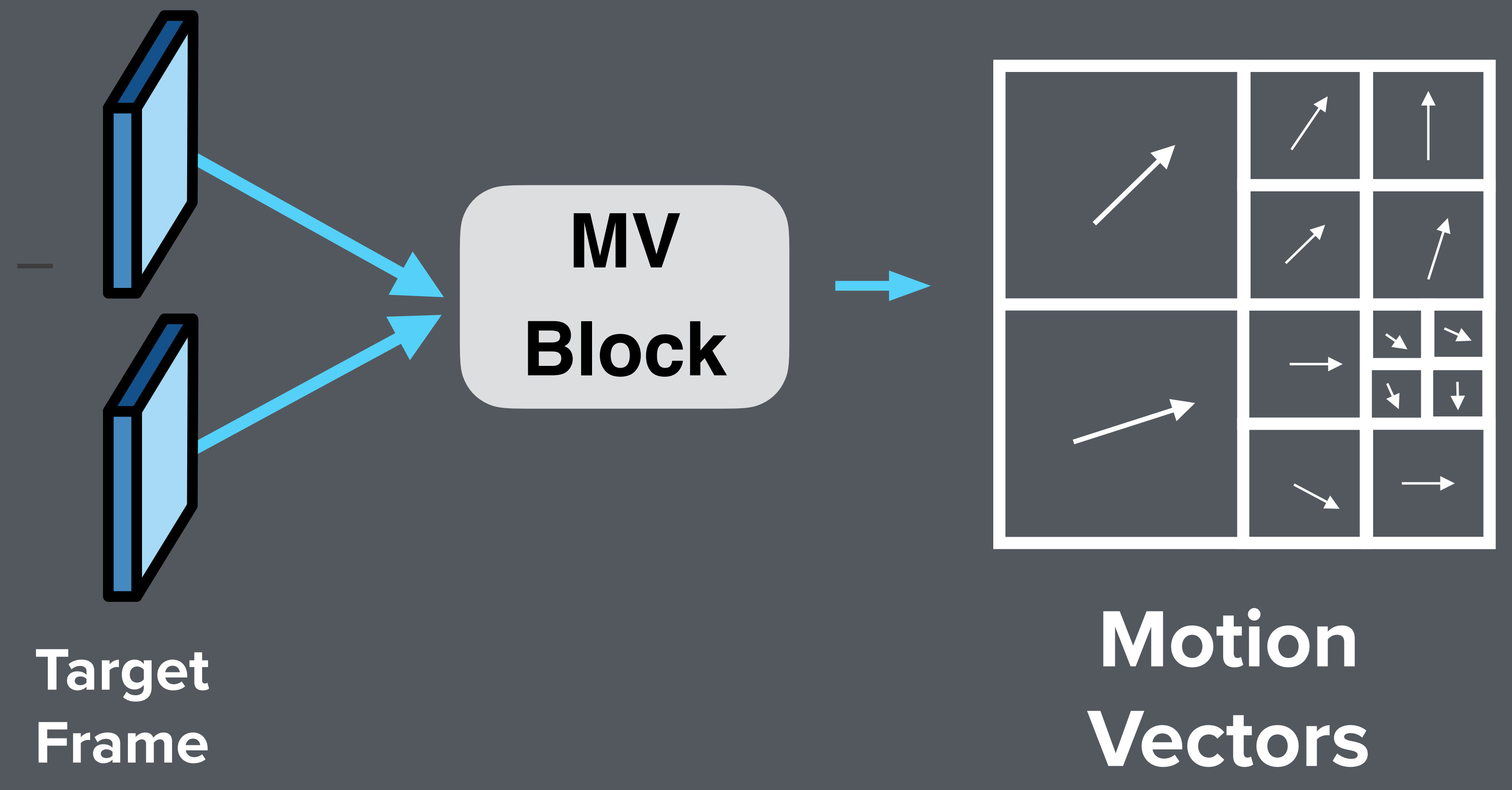
Motion-compensated

Target

Residual

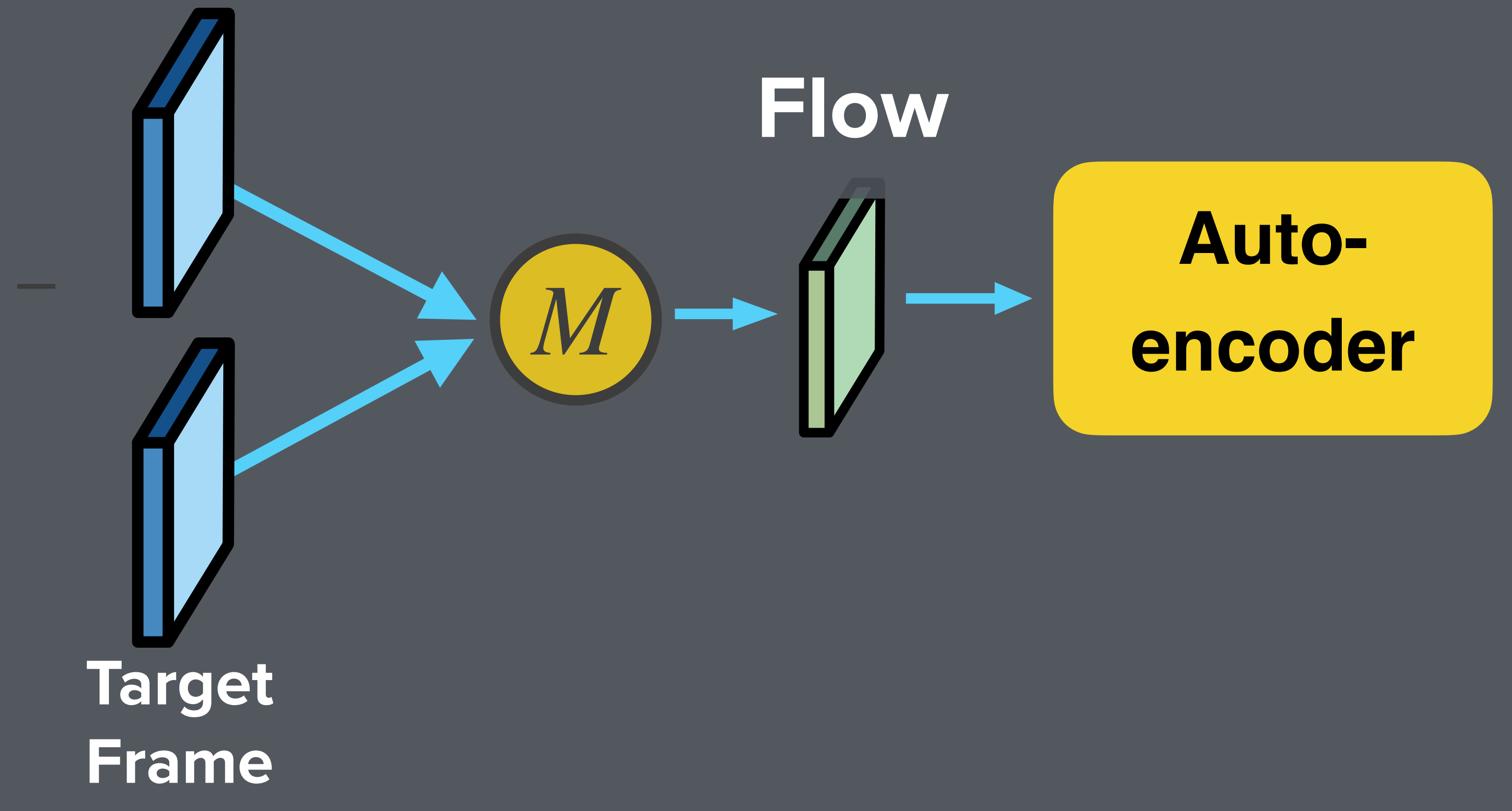
Better understanding of motion

Traditional



- Axis-aligned blocks
- Discretized motion directions and magnitudes

Learned Motion



- Motion is pixel-wise
- Network decides the tradeoff in accuracy vs bits of Flow compression

Motion-compensated

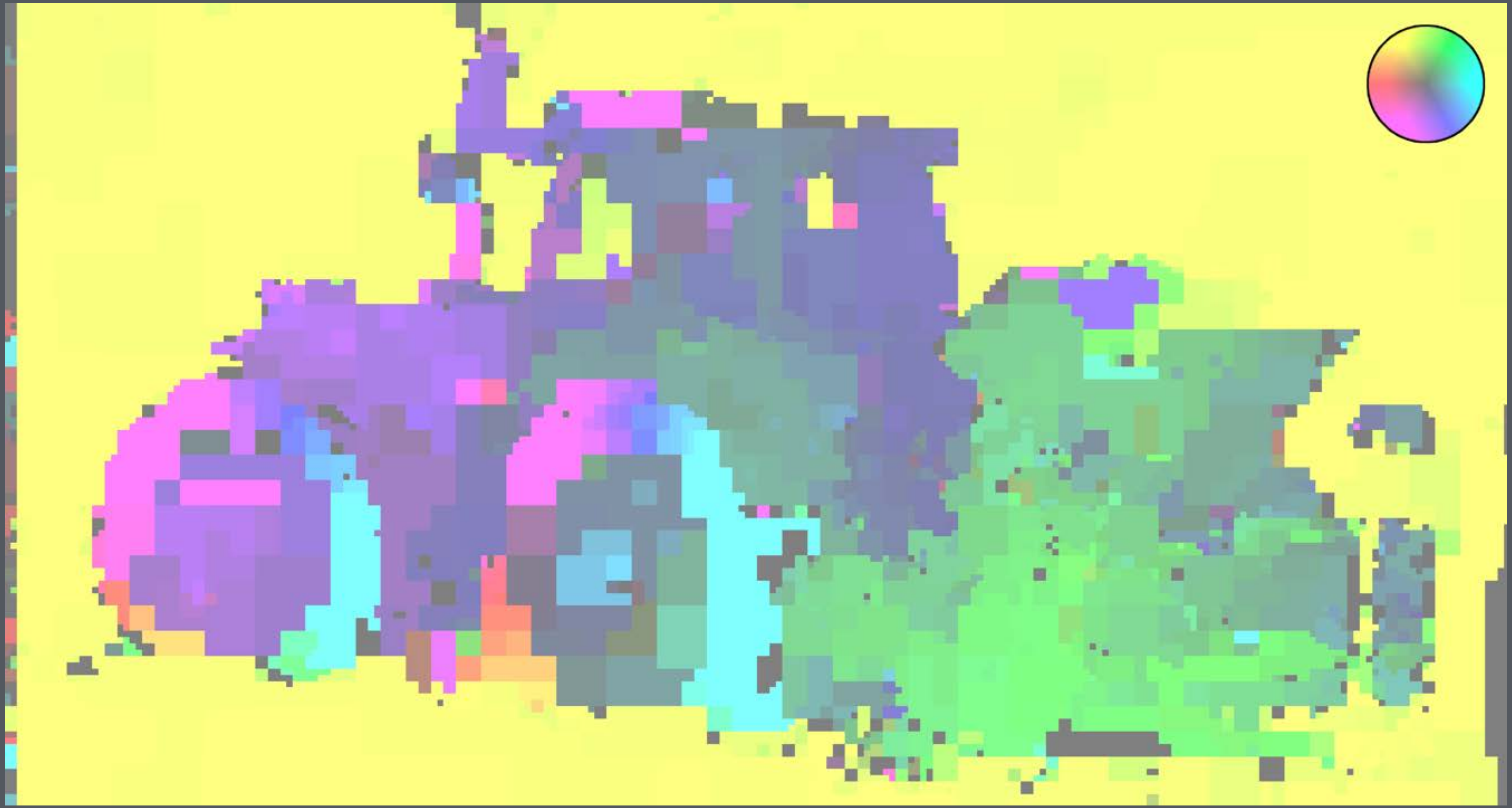
Target

Residual

Example: Tractor Video

Motion-compensated | Target | Residual

Example: Tractor Video

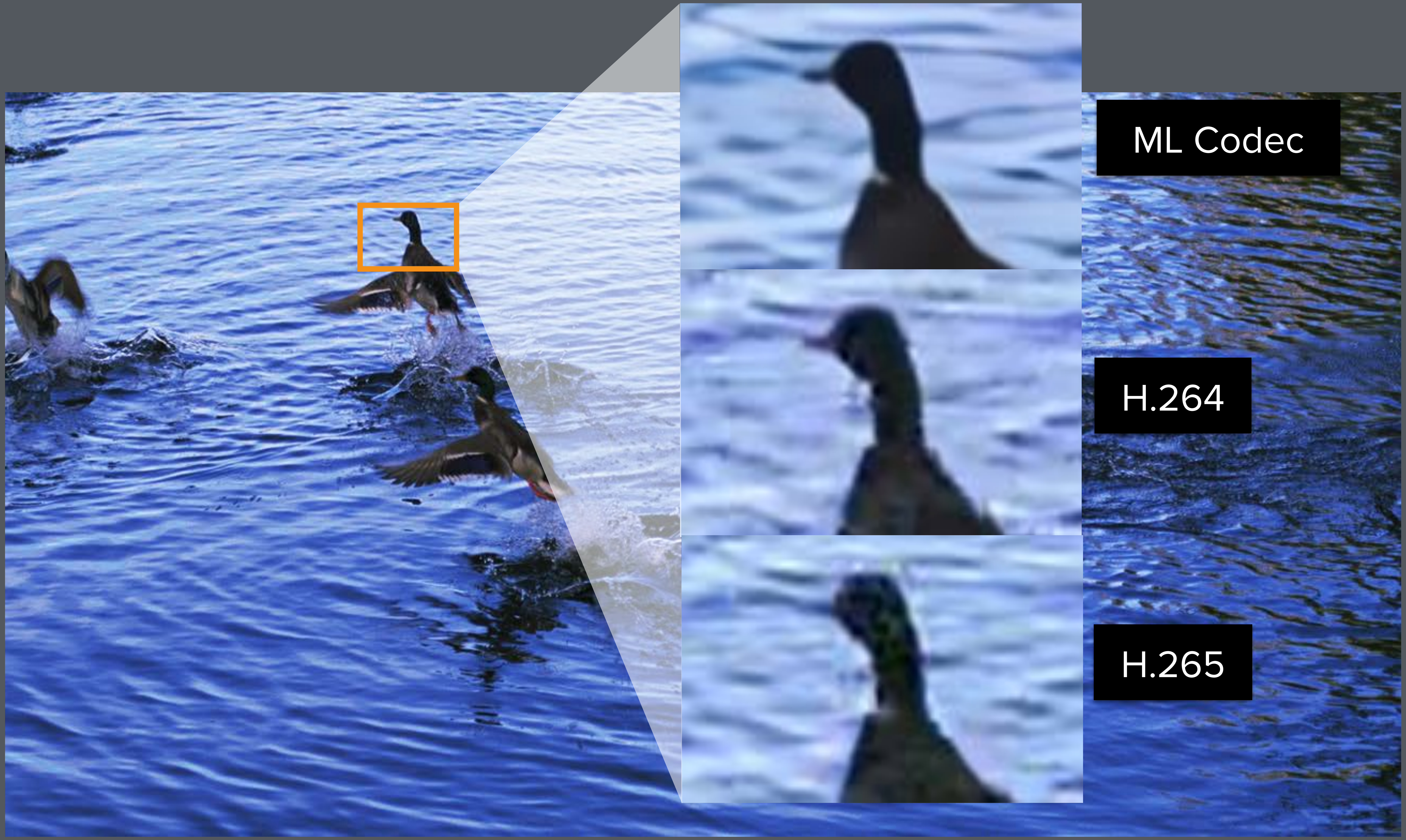


Motion-compensated Target Residual

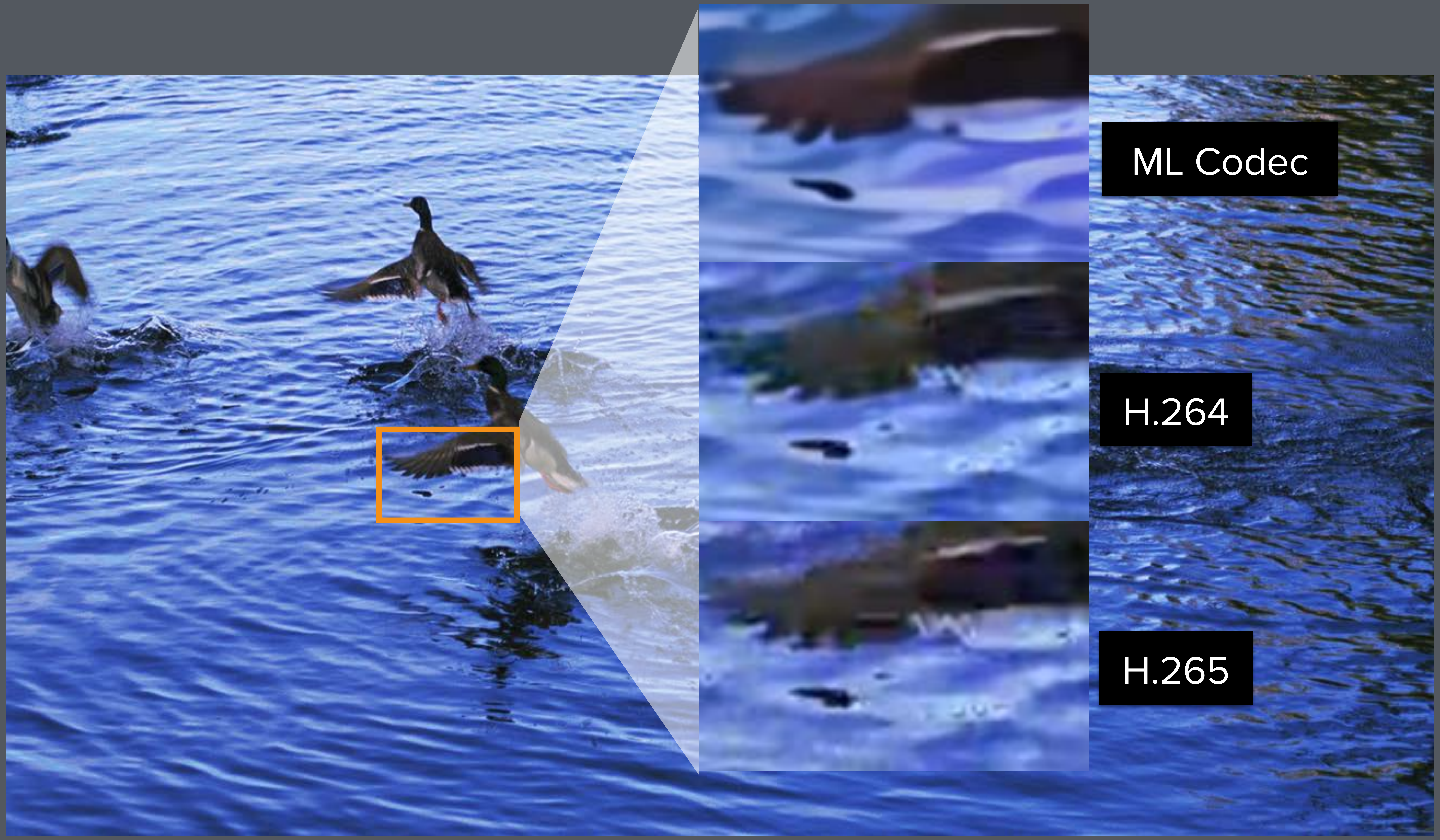
Example: Tractor Video

Motion-compensated Target Residual

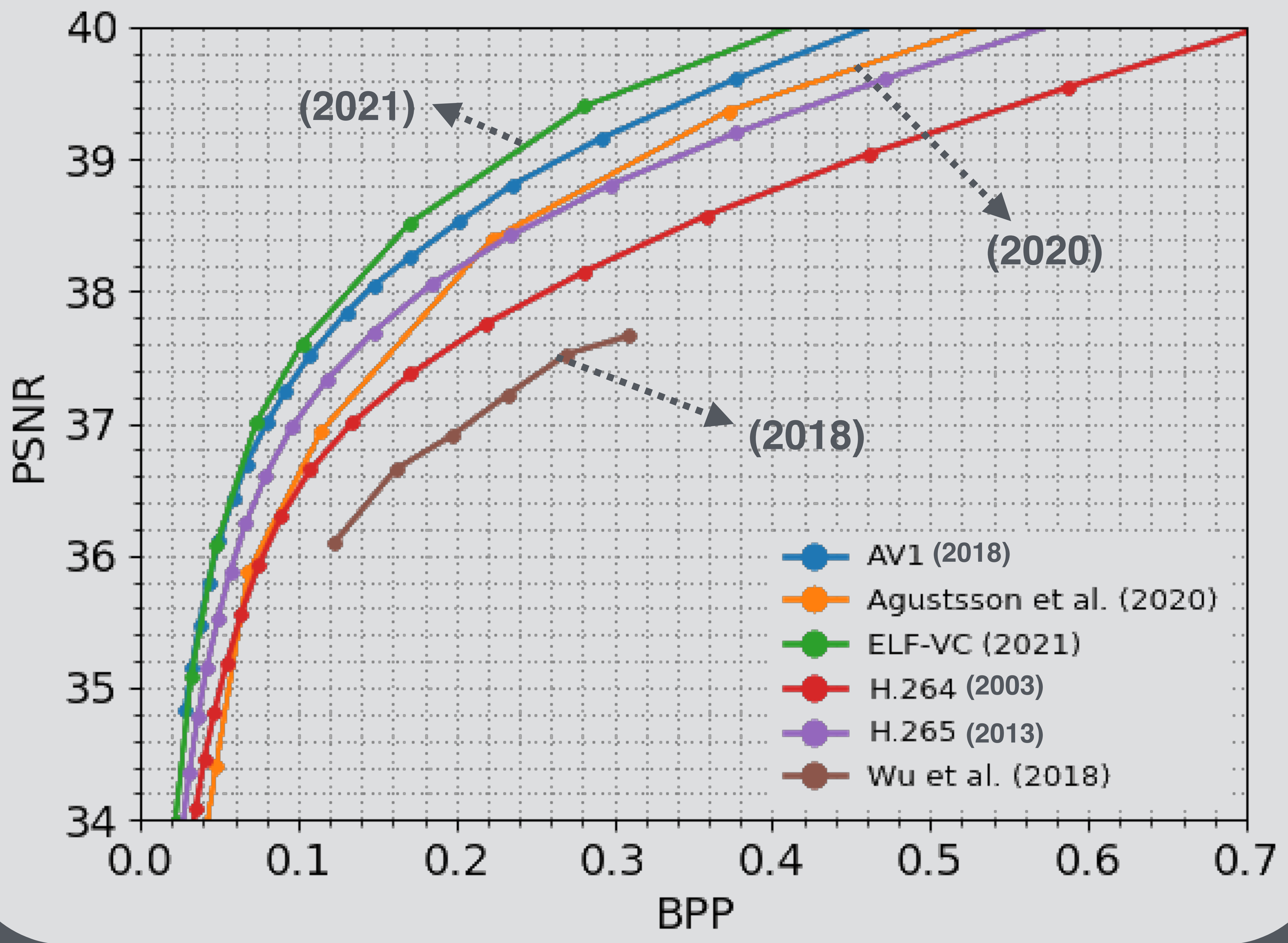
Example: Ducks Take Off



Example: Ducks Take Off

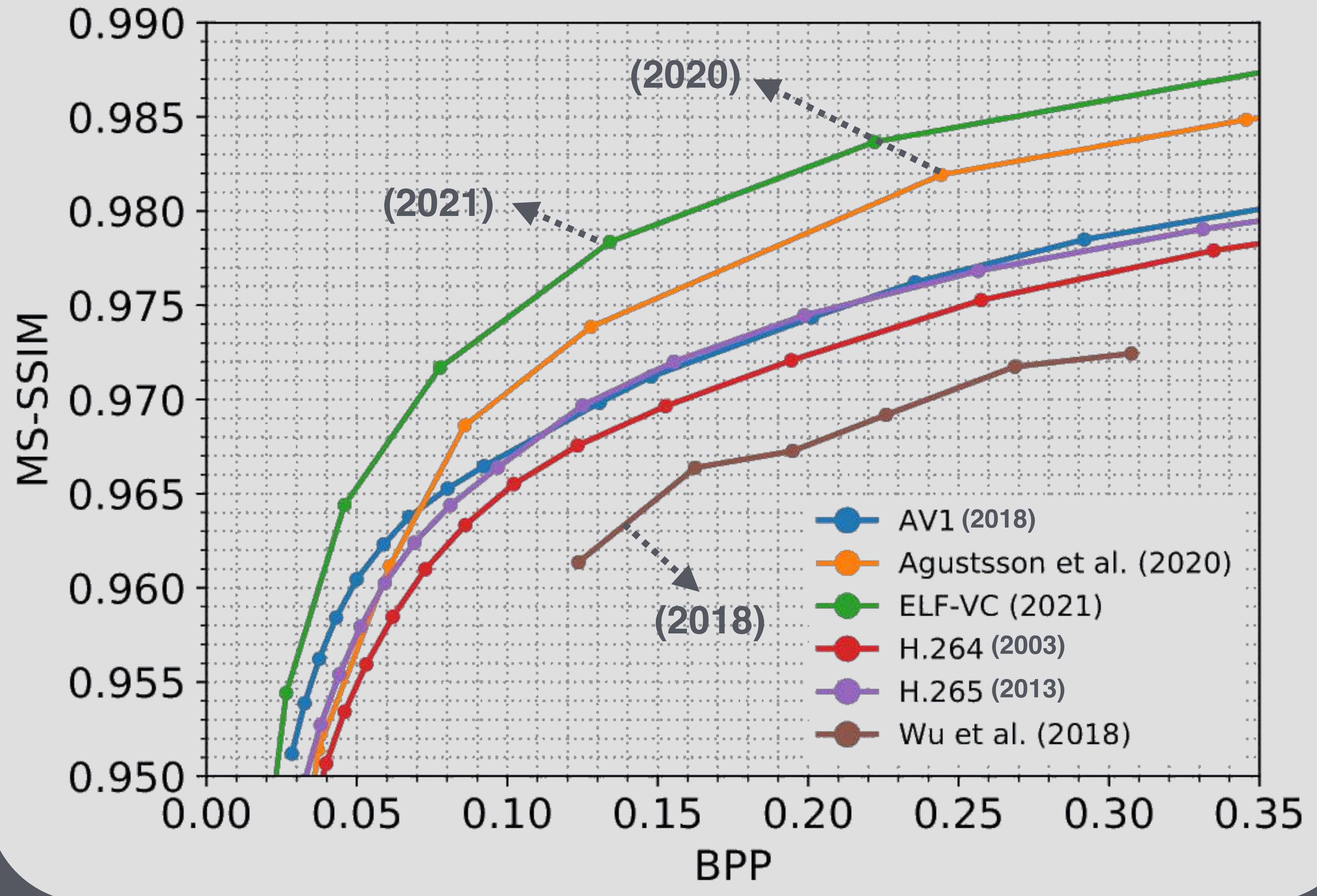


Learned Video Codecs: PSNR



Results on UVG dataset, low-latency setting, PSNR, keyint=16

Learned Video Codecs: MS-SSIM



Results on UVG dataset, low-latency setting, MS-SSIM, keyint

Video Compression -> Conclusion

- **Conceptually Simple -> Motion + Residual coding:**

  Uses 2-step approach -> find and encode motion, encode the residual. The complexity comes in how to implement these blocks.

- **Lots of parameters:**

  keyint=?,

  How many I,P,B?

  How many bits to give to each frame? (“Rate control”)

- **ML-based codecs:**

  Significant improvements in the past 2-3 years, but lot more to come!

Motion-compensated

Target

Residual

Video Compression -> Conclusion

- **Conceptually Simple -> Motion + Residual coding:**

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  Significant improvements in the past 2-3 years, but lot more to come!

Motion-compensated Target Residual

EE274: Course Summary

Motion-compensated Target Residual

EE274 Summary -> IID Data

- **How to compress i.i.d data?**

  Prefix-free codes, Huffman codes, Arithmetic coding, rANS
- Mainly useful as a building block for other fancier compressors

Motion-compensated Target Residual

EE274 Summary -> IID Data

- **Entropy and Information theoretic limits**

  "What is the best you can compress you data?" Entropy ->

- **Using Information theory for generic lower bounds**

  A very useful technique used in CS Theory etc.. (you got a glimpse from the "find the best rower problem" in HW3

Q5: Lower Bounds via Information Theory (*35 points*)

At the annual *Claude Shannon rowing contest*, there are n participants, with $n-1$ out of them having exactly same strength but one of the rowers is exceptionally strong. The contest aims at finding that one strongest rower. The competition organizers are unfortunately limited on the funds, and so want to minimize the number of rounds to declare the winner.

Residual

EE274 Summary -> Non-iid data

- **Lossless compression of non-iid data:**

  Key-idea -> *"If you model your data well, Arithmetic coding for order-k is optimal"*

- **What if you don't want to model your data?**

  Universal Lossless compressors -> can be shown to be optimal *asymptotically* on any source

  LZ77, LZ78, BZIP, ZStandard …

Motion-compensated Target Residual

EE274 Summary -> Lossy compression fundamentals

- **Rate distortion theory:**

  "What is the fundamental limit on lossy compression given a distortion?"

- **Vector Quantization, Transform coding**

  Theory gets quite difficult when we come to lossy compression :-|

  But, lots of good insights!

Motion-compensated Target Residual

EE274 Summary -> Applications

- **Image compression**

  JPEG, ML-based image compression, …

- **Audio, Video Compression**

  H264, HW3 problem on audio compression, …

"Key concepts are kind-of similar across all the domains.. Transform coding, Residual coding, and finally some lossless coding"

Motion-compensated

Target

Residual

EE274 -> What we didn't get to

- **Distributed Compression**

  How do we jointly compress data from multiple sources? (Puzzle in HW2 gives a sense)

- **Succinct Data Structures**

  "How can we compress data structures so that they fit on the RAM? But still have their properties intact?" -> eg: searching over compressed text

- **Compression of ML-models, Compression in HW**

  Very interesting line of work, with lots of interesting problems.

Motion-compensated Target Residual

EE274 -> What next?

- **Stanford Compression Library**
- **EE274 Resources**

https://stanforddatacompressionclass.github.io/notes/resources.html

Resources

Interested in data compression? Great! We list a few resources (apart from the lecture notes) which might be useful to take a look.

NOTE: If you find a resource which you found useful and is not listed here, please file an github issue at https://github.com/stanfordDataCompressionClass/notes.

Motion-compensated

Target

Residual

EE274 -> What next?

- **EE276 -> Information Theory**
- **EE376 -> Topics in Information theory**
- **MUSIC 422 -> Perceptual Audio coding**
- **CS 228 -> Probabilistic Graphical Models**

…

1 - 1 of 1 results for: **MUSIC 422: Perceptual Audio Coding**

MUSIC 422: Perceptual Audio Coding

History and basic principles: development of psychoacoustics-based data-compression techniques; perceptual-audio-coder applications (radio, television, film, multimedia/internet audio, DVD, EMD). In-class demonstrations: state-of-the-art audio coder implementations (such as AC-3, MPEG) at varying data rates; programming simple coders. Topics: audio signals representation; quantization; time to frequency mapping; introduction to psychoacoustics; bit allocation and basic building blocks of an audio codec; perceptual audio codecs evaluation; overview of MPEG-1, 2, 4 audio coding and other coding standards (such asAC-3). Prerequisites: knowledge of digital audio principles, familiarity with C programming. Recommended: 320, EE 261. See http://ccrma.stanford.edu/.

Terms: Win | Units: 3

Instructors: Bosi, M. (PI) ; Hodges, A. (TA)

Schedule for MUSIC 422

Residual

Thank You!

Motion-compensated Target Residual